26793

manual

instruction

IM-5840 (1)
Beckman Inst.

MERL
NELSON
R. F. Lab.
048 LIBRARY
SEP 20 1963

INSTRUCTION MANUAL

Model 5840 Series
MAGNETIC DUAL PRESET
CONTROLLER

Beckman®
Berkeley Division

RECEIPT FOR S&ID TIC DATA 9-11-63

REQUESTOR Price, Carl DATE _____
(LAST NAME FIRST - PLEASE PRINT)

DEPT. 048 GROUP _____ EXT. _____

TITLE OR SOURCE Beckman Inst. AUTHOR OR CLASSIF. Unc

BOOK CALL OR DOCUMENT NO. IM-5840 COPY NO. 1

The above document, property of NORTH AMERICAN AVIATION, INC., HAS been received by the undersigned, and if classified, will be used under the terms of my employment secrecy agreement. Failure to exhibit during an accountability check, return the document at the expiration of the loan period, or at the time of an employee's termination, will result in a payroll deduction equal to amount to the replacement cost of the document.

RETURN DATE 26793

NOTE: THIS DATA IS NOW OVERDUE. PLEASE RETURN TO LIBRARY IMMEDIATELY.

SIGNATURE _____

FORM 923-V REV. 2-62 TIC – 1ST FOLLOW UP

048 LIBRARY
SEP 20 1963

INSTRUCTION MANUAL

Model 5840 Series
MAGNETIC DUAL PRESET CONTROLLER

RECEIVED
SEP 11 1963
Technical Information Center
S&ID

Lot and above

BERKELEY division
Beckman Instruments, Inc.

Richmond 3, California
13 April 1956

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect.

(b) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(c) The Company shall be released from all obligations under its warranty in the event repairs or modifications are made by persons other than its own service personnel or authorized representatives' personnel unless such repairs by others are made with the written consent of the Company.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

Copyright 1956
Berkeley division BECKMAN INSTRUMENTS INC.

Contents

	Page
Introduction	
General Description	1
Specifications	1
Applications	2
Operation	
Control and Terminal Functions	3
Mounting the Controller	4
Line Power Connections	4
Input Requirements	4
Input Connections and Adjustments	5
Presetting the Count	6
Selecting Automatic, Manual or Remote Reset	6
Output Signal Characteristics	6
Counting without Relay Output	8
Testing Tubes	8
Circuit Description	
Over-all Design	9
Power Supplies	10
Servicing	
Routine Maintenance	12
Troubleshooting	12
General Procedure	12
Table of Common Troubles	12
Checking Power Supplies	13
Trouble Localizing Procedure	14
Troubleshooting a Particular Circuit	15
Typical Waveforms	16
Interior Views Showing Location of Parts	20
Block Diagram, Model 5840 Series	
Schematic Diagram, Entire Equipment except Power Supplies, Model 5840 Series, Dwg. No. 5846D2	
Schematic Diagram, D-C and R-F Power Supplies, Model 5840 Series, Dwg. No. 5846D1	
APPENDICES	
Elementary Circuits Using Ferristors*	
Instruction Manual, Model 736 Decimal Counting Units	

* "FERRISTOR" IS THE TRADEMARK APPLIED TO SATURABLE REACTORS MANUFACTURED BY THE BERKELEY DIVISION OF BECKMAN INSTRUMENTS, INC.

Model 5846

Introduction

GENERAL DESCRIPTION

The Magnetic Dual Preset Controller is a high-speed electronic counter which will produce output signals at any two selected number of counts. The unit will count any physical events which can be translated into current changes at the input terminal. It will count at any rate up to 10,000 events per second. Output signals are available in the form of relay openings and closures or changing d-c voltage levels at output terminals. These signals can be used to control processes automatically or to sound alarms alerting personnel. The accumulated count is displayed continuously in digital form on the front panel of the controller.

Several models of the controller will be available which differ only in count capacity. These are Models 5843, 5844, 5845 and 5846. The last digit in the model number of each denotes the number of digits it displays. For example, the Model 5843 displays three digits and will consequently count to 999. The other models have count capacities of 9,999, 99,999 and 999,999 respectively.

The controller has been designed especially to operate continuously without breakdown in a factory environment. A magnetic component, the Berkeley Ferristor*, has been used in place of the conventional vacuum tube in nearly all circuitry. Ferristors do not deteriorate with use or age and cannot be damaged by shock, vibration or moisture. Since they generate so little heat that ventilation is unnecessary, the counting circuitry is protected by a dust-tight cabinet. Even unventilated the interior temperature is not high enough to cause the slow heat deterioration of components that often occurs in electronic devices. As an additional safeguard against breakdown, nearly all circuits are operated at less than 25% of component ratings. The controller contains only two vacuum tubes. These may be checked periodically to see whether they are becoming dangerously weak simply by moving a toggle switch inside the cabinet to a "TEST" position. Weak tubes may be replaced before they cause faulty operation.

SPECIFICATIONS

Counting Rate:

zero to 10,000 counts per second

NOTE: Maximum counting rate permitting reset to zero without losing a count is 10,000 per second in the case of Models 5843 & 5844 and 8,000 per second in the case of Models 5845 & 5846.

Count Capacity:

Model 5843:	999
Model 5844:	9,999
Model 5845:	99,999
Model 5846:	999,999

Accuracy:

Absolute

Sensitivity:

100 Microamperes peak-to-peak into 10,000 ohms in series with 60 millihenries

Input Level Bias Range:

± 1 milliampere

Operating modes:

Manual reset or automatic reset at higher preset count

*Trademark

Outputs Available:

At each preset count: a voltage pulse and a DPDT relay movement. Relay movement may be either momentary (adjustable from 0.2 to 1 sec.) or "held".

Remote Reset:

From external contact closure.

Supply Voltage:

50-60 cps. Switch selects taps at 105, 117, and 126 volts ± 15%.

Power Required:

Approx. 85 watts.

R-F Oscillators:

2 Type 6146 Tubes.

Dimensions:

18-7/8" wide, 8-23/32" high, 13-5/8" deep (overall). Fits in standard relay rack. May be mounted on wall.

Weight:

50 lbs.

APPLICATIONS

The Model 5846 may be used to control a wide variety of industrial processes including counting, weighing, sorting, packaging, shearing, and metal forming. It can be used to cut off motors, turbines or jet engines at a precise predetermined speed or total number of revolutions. It may also be used to time computers.

Winding electric coils is a typical operation which may be controlled by this equipment. In this case the input to the controller is the output of a tachometer. The tachometer is attached to the coil form so that as the form rotates, adding turns of wire, an output signal from the tachometer triggers counts on the controller. At the first preset count (count "A"), "A" relay contacts add resistance in series with the motor which is turning the coil form, causing the motor to slow. At the second preset count, opening "B" relay contacts disconnect power from the motor and apply a brake. In this way most of the coil can be wound at high speed to save time, then slowed to enable stopping at a precise number of turns without undue strain on equipment.

CONTROL AND TERMINAL FUNCTIONS

CONTROLS

TEST-OPERATE Switch

Located above main terminal strip. Placed briefly at TEST to check vacuum tubes. See "Testing Tubes".

ON-OFF Switch

Connects line power to all circuitry. See "Line Power Connections".

CONTROL Switch

Disconnects output relays from controller. See "Counting Without Relay Output".

INPUT LEVEL ADJUST Control

Sets point on input current waveform at which counts are triggered. See "Input Connections and Adjustments."

PRESET COUNT Switches

On front panel. Top row labeled "A"; bottom row, "B". Select number of counts at which first (A) and second (B) output signals occur. See "Presetting the Count".

AUTO-MAN Switch

On rear of hinged indicating panel. Selects operating cycle including automatic reset to zero at count B or operation requiring manual reset with front panel button or external switch. See "Selecting Automatic, Manual or Remote Reset".

MC-HOLD Switches

One for each output channel (A & B) at rear of hinged indicating panel. Selects momentary or "held" relay movement. See "Output Signal Characteristics".

MC-PERIOD Controls

Located near MC-HOLD switches. Adjusts duration of momentary relay movement when adjacent switch is at MC. See "Output Signal Characteristics".

TERMINALS

All terminals are located on a strip exposed when the indicating panel is swung out and a dust baffle behind it is unlatched and swung forward and down.

GND Terminal

Connected to chassis

L1 and L2

Line power terminals. See "Line Power Connections".

SPARE Terminals

Not connected. May be bussed to GND terminal to obtain additional connections to chassis.

K101 Terminals 1 to 6

Connected to B output relay contacts. See "Output Signal Characteristics."

K102 Terminals 1 to 6

Connected to A output relay contacts. See "Output Signal Characteristics".

PULSE OUTPUT

A Pulse occurs at terminal A at preset count A and a pulse at terminal B at count B. See "Output Signal Characteristics".

EXT RESET

Controller resets when these terminals are individually grounded. See "Selecting Automatic, Manual or Remote Reset".

INPUT

Signal to be counted must be applied between this terminal and the GND terminal. See "Input Connections and Adjustments".

INSTALLATION AND OPERATING PROCEDURES

MOUNTING THE CONTROLLER

The controller may be mounted in nearly any convenient location. It will operate well at any room temperature tolerable to personnel. Do not, however, mount it in an intense magnetic field such as would exist on top of a large electric motor or within a few feet of a large power transformer. The unit may be mounted on wall brackets which will fit into the horizontal slots at the rear of the cabinet. It will also fit into a standard relay rack without removing the cabinet. All electric connections are made on the terminal strip which is exposed when the indicating panel is swung out and dust baffle is dropped down. Four knock-out holes in the cabinet near this terminal strip may be used to connect conduct carrying the connecting wires.

LINE POWER CONNECTIONS

The controller will operate on 117 or 230 volts a-c single phase, 50 to 60 cps. It draws about 85 watts. The socket J203 located just above the terminal strip takes one of two plugs depending upon the line voltage used. If the unit is to be operated on 230 volts, insert the plug labeled "210V-231V" into this socket. If 117 volts is to be used, insert the plug labeled "105V-126V."

Connect the line power leads to terminals L1 and L2. Ground the terminal labeled "GND". The plug P202, located near J203, should be inserted in one of three possible positions depending upon whether the line voltage is unusually high, unusually low or just about right. Measure the line voltage and plug in P202 so that the arrow printed on the plug points to the voltage which is nearest the actual line voltage. To apply power make sure the TEST-OPERATE switch is at OPERATE. Then move the front panel ON-OFF switch to ON.

INPUT REQUIREMENTS

The INPUT terminal is connected to the control windings of the first magnetic amplifier in the counter as shown in Figure 1. The control windings are the magnetic equivalent of the control grid of a vacuum tube amplifier with this important difference: the magnetic amplifier is sensitive only to current variations in the control windings whereas the vacuum tube is sensitive to voltage variations on the grid. For this reason the input requirements of magnetic circuits are usually stated in terms of current. Note on Figure 1 that the current in the control windings is the sum of two currents: the current flowing at the INPUT terminal and a d-c bias current created by the INPUT LEVEL ADJUST. The bias current can be varied from zero to -2000 μa. (A negative current is defined here as that produced by a voltage at the control windings negative with respect to ground.)

Figure 2 shows how a varying current in the control windings produces counts. One count is produced each time the current in the control windings changes from -950 μa to -1050 μa. This requires current variations at least 100 μa peak-to-peak. After a count at -1050 μa the current must vary to -950 μa or farther positive and back again to -1050 μa to trigger a second count. In this way one count is produced for each cycle.

If the input current is an a-c signal fluctuating, for example from +75 to -75 μa, the bias current must be adjusted to about -1000 μa so that the resultant control current will vary above -950 μa and below -1050 μa. However, if the input were a similar a-c signal riding on a d-c level of +500 μa, the bias current would have to be increased to -1500 μa to create the proper control current.

Since maximum counting rate is 10,000 counts per second, the input frequency must not be higher than 10KC. In the case of a pulse input, the current pulses must be at least 10 μseconds wide and must not occur at intervals shorter than 100 μseconds. Pulses may be either positive or negative.

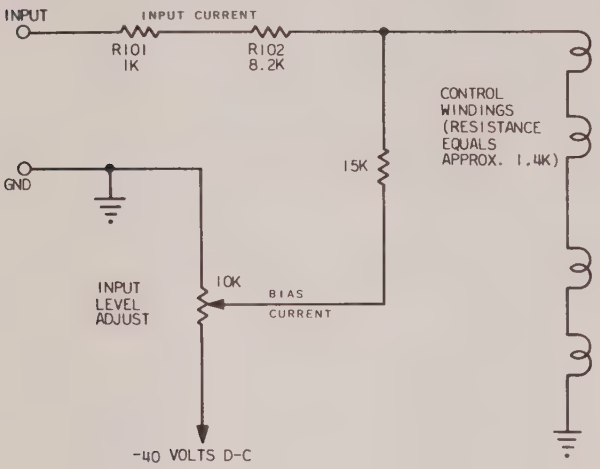


FIGURE 1. INPUT CIRCUITRY

The impedance between the INPUT terminal and ground is 10.6K in series with 60 millihenries. For most input signals the inductive reactance is not appreciable even at the maximum input frequency of 10KC. (The inductance becomes important only when the input is a narrow voltage pulse of small amplitude. Such pulses must be high enough and wide enough to create the minimal current pulses described in the preceding paragraph.) Neglecting the inductive reactance and considering only the 10.6K input resistance, it follows the voltage between the INPUT terminal and ground must vary at least 1 volt to produce 100 μa current variations in the control windings and in that way trigger counts. The INPUT LEVEL ADJUST will compensate for any d-c level in the range of -10 to +10 volts at the INPUT. To avoid damaging the equipment the voltage at the INPUT terminal should never rise above 50 volts peak-to-ground.

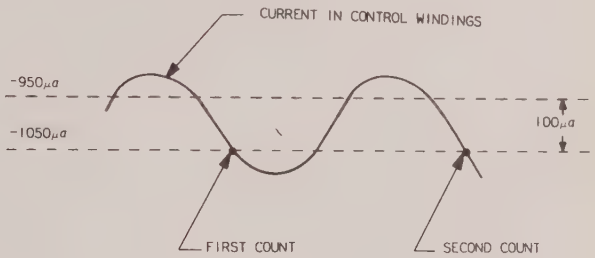


FIGURE 2

Resistors R101 and R102, shown in Figure 1 connected in series between the INPUT and the control windings, serve only to protect the windings from excessive current. The sensitivity of the controller may be increased by shunting these resistors, but great care must be taken to see the current in the control windings does not use above 25 milliamperes d-c or rms.

INPUT CONNECTIONS AND ADJUSTMENTS

Apply the input signal voltage between the INPUT terminal and the GND terminal. Adjust the INPUT LEVEL ADJUST control located just behind the indicating panel near the right-hand decimal counting unit. See "INPUT REQUIREMENTS" to learn how this control operates. Ordinarily, a satisfactory adjustment may be made by the following procedure:

1. Place the TEST-OPERATE switch at OPERATE.
2. Turn the front panel ON-OFF switch ON.
3. Place the AUTO-MAN switch at AUTO. (This switch is located on the back of the hinged indicating panel).
4. Rotate the INPUT LEVEL ADJUST all the way counter-clock-wise.
   Turning this control slowly clockwise note the position at which counting begins and the position at which it stops. Set the control midway between the start position and the stop position. If the instrument continues counting all the way to one or both extremes of rotation, simply set the control in the center of the range in which counting occurs.

PRESETTING THE COUNT

Rotating the knobs on the front panel sets the two counts at which the controller generates output signals. The row marked "A" sets the earlier or lower count and that marked "B", the later or higher count. The number formed by the top digits on the knobs (the digits opposite the black lines) when read from left to right is the count at which output signals occur. You may set any number from 1 to 1, 000, 000 (000, 000) on either the A or the B row.

SELECTING AUTOMATIC, MANUAL OR REMOTE RESET

The position of the "AUTO-MAN" switch at the rear of the hinged indicator panel determines whether the counter returns to zero automatically at count B or must be manually reset to begin a new count. With the switch at AUTO, the controller counts to count A, produces output signals, continues counting to count B, produces more output signals and simultaneously resets to zero. After reset the controller is ready to begin counting again when an input signal appears. (For a brief period after count B the controller will not score another count should an input signal occur. This "dead" period is 100 μseconds in the case of Models 5843 & 5844 and 125 μseconds in the case of Models 5845 & 5846.) Ordinarily, under automatic operation output signals at count B will halt the activity which was monitored up to that time and initiate some new activity which produces another input signal. Even with the AUTO-MAN switch at AUTO the counter can be reset to zero if desired by pressing the manual RESET button.

With the switch at MAN, the controller counts A, produces output signals, continues counting to count B, produces more output signals and continues counting still higher if an input signal is still present. The operator must press the RESET button or ground both EXT RESET terminals individually to reset the DCU's to zero. To arrange reset from a remote location connect separate leads to the EXT RESET terminals. To reset, ground both leads through a double-pole single-throw switch. These terminals must not be bussed except at the moment both are grounded. Ordinarily, under manual operation, an output signal at count B will halt whatever activity is producing input signals so that no counting whatever will occur from count B until reset.

OUTPUT SIGNAL CHARACTERISTICS

There are two output channels. One is activated when preset count A is reached and the other when count B occurs. Figure 3 shows the output circuitry and the switches which affect the output of each channel. Two types of output are available at each channel regardless of switch settings: a relay movement which makes and breaks connections at terminals 1 thru 6 and a voltage pulse at the PULSE OUTPUT terminal. The relay contacts are rated to withstand 115 volts at 5 amps or 230 volts at 2 1/2 amps in a non-inductive load circuit. These relays make or break 10 to 15 milliseconds after a preset count occurs. Faster relays are available.

"A" RELAY OUTPUT

(1) With MC-HOLD switch at HOLD:

Relay is de-energized from reset (count zero) until count A.

Relay is energized from count A until reset.

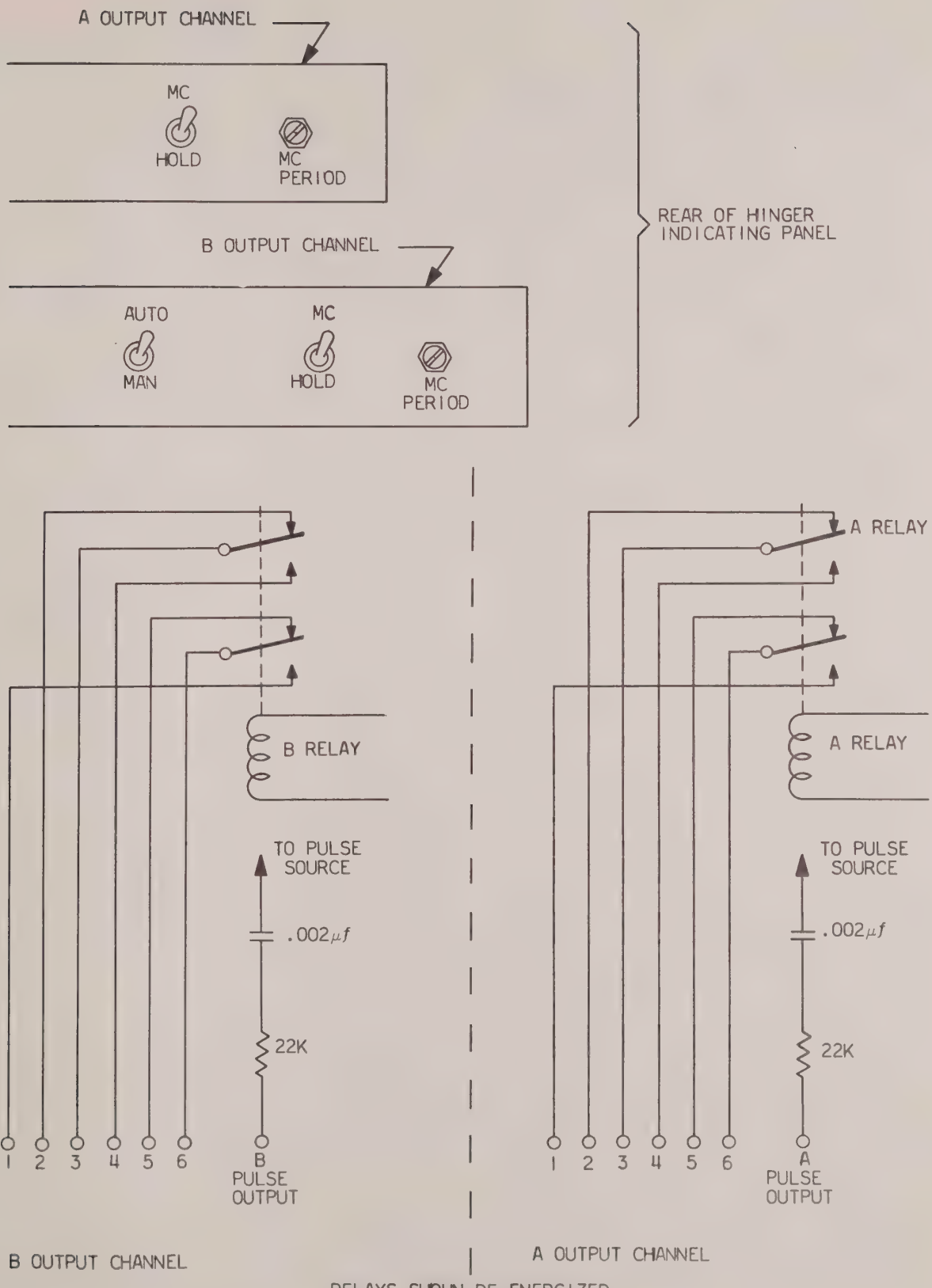


FIGURE 3 OUTPUT CIRCUITRY AND CONTROLS

(2) With MC-HOLD switch at MC (momentary closure), relay is de-energized at all times except at count A when it becomes energized for from 0.2 seconds to 1 second depending upon setting of MC PERIOD control.

"B" RELAY OUTPUT

(1) With MC-HOLD switch at HOLD

(a) and AUTO-MAN switch at MANual
Relay is de-energized from reset (count zero) until count B.
Relay is energized from count B until reset.

(b) and AUTO-MAN switch at AUTOmatic
Relay is de-energized from manual reset until count B. Thereafter it switches back and forth between de-energized and energized conditions as conditions as successive count B's occur.

(2) With MC-HOLD switch at MC relay is de-energized at all times except at count B when it becomes energized for from 0.2 seconds to 1 second depending upon setting of MC PERIOD control.

"A" AND "B" PULSE OUTPUT

The signals at the PULSE OUTPUT terminals are not affected by the controls at the rear of the hinged indicating panel. At the "A" PULSE OUTPUT terminal a 15-volt negative transient occurs at count A followed by a 15-volt positive transient at count A plus one. At the "B" PULSE OUTPUT terminal a positive pulse 15 volts high and 40 μseconds wide occurs at count B. The output impedance at both terminals is 22K. These terminals may be shorted to ground without impairing the operation of the counter.

Whether the relay or the pulse output is used and whether the relay movement shall be momentary or "held" depends entirely upon the type of equipment being controlled.

COUNTING WITHOUT RELAY OUTPUT

When the front panel CONTROL switch is OFF the output relays are disconnected from the controller and both are de-energized. In this condition the operator may check counting for accuracy before applying a control signal to other equipment. The CONTROL switch does not affect the pulse output.

TESTING TUBES

To insure that tube deterioration does not cause a failure in operation test the tubes weekly at some time when the controller is not needed in operation. To do this move the CONTROL switch to OFF to de-energize the output relays and move the TEST-OPERATE switch above the terminal board to TEST. This reduces the tube heater voltage and supplies a 60 cps signal which is counted in place of the input signal. If either tube is dangerously weak, counting will stop within one minute. Replace weak tubes immediately to forestall failure. Do not leave the TEST-OPERATE switch at TEST longer than necessary to make the check. Prolonged operation at this position will damage the tubes.

Circuit Description

NOTE: The magnetic circuits referred to here (amplifiers, current discriminators, one-shots and bi-stable circuits) are described in detail in the section entitled "Elementary Circuits using Ferristors." The preset decimal counting units are described in an appendix.

OVER-ALL DESIGN

Figure 8 is a block diagram of the controller. The input amplifier simply amplifies the signal appearing at the INPUT terminal. The current discriminator generates a sharp pulse for each input signal cycle. The first one-shot amplifies these pulses sufficiently to drive the succeeding decimal counting units and gates. The decimal counting units count and register the number of pulses produced by the first one-shot. These pulses are first applied to the "units" decimal counting unit and the second one-shot, which acts as an electronic gate. Each one shot gate is "open" only when a DCU is supplying a bias current to it. A DCU produces a bias current only when it is registering "9". Consequently, the first nine pulses are counted on the "units" DCU but do not pass through the gate to the "tens" DCU. The tenth pulse occurs while the "units" DCU is registering "9" so it passes through the gate and scores a count on the "tens" DCU. In the same way only every tenth pulse reaching the "tens" DCU (i.e. every hundredth input pulse) passes through the next gate to the "hundreds" DCU.

Each DCU draws current through the "A" coincidence line except when it is registering the digit to which its A preset switch is set. The sum of the currents drawn by all DCU's is amplified by the "A" coincidence preamplifier and applied to the "A" coincidence amplifier. The current drawn by any one of the DCU's is alone sufficient to hold the "A" coincidence amplifier in the saturated state. At count A all the DCU's simultaneously register the digit preset on each, so no current flows in the "A" coincidence line and the "A" coincidence amplifier is suddenly de-saturated. The resultant drop in output voltage is differentiated to produce a negative pulse. This pulse is coupled to the A PULSE OUTPUT terminal and to the "A" relay amplifier.

The "A" relay amplifier operates as a one-shot when the MC-HOLD switch is at MC and as a bi-stable circuit when the switch is at HOLD. At MC the output pulse produced energizes the "A" relay momentarily. At HOLD the negative input pulse triggers the relay amplifier to a stable state in which a high output voltage holds the "A" relay energized. The circuit is triggered back to the other stable state (in which the relay is de-energized) by a positive reset pulse applied at the input.

The "B" coincidence preamplifier and amplifier operate in the same way as the "A" coincidence preamplifier and amplifier. At count B current flowing in the "B" coincidence line ceases, causing a sudden drop in the output voltage of the "B" coincidence amplifier, which is differentiated to produce a positive pulse. This positive pulse, amplified by the reset one-shot, performs three functions. First, it is coupled to the "B" PULSE OUTPUT terminal. Second, if the AUTO-MAN switch is at AUTO, it is coupled to the reset line. (The pulse on the reset line resets all decimal counting units to zero and triggers the

"A" relay amplifier to a state which de-energizes the "A" relay if it has been energized.) Third, it is further differentiated to produce a positive pulse followed closely by a negative pulse which are both applied to the input of the "B" relay amplifier. Like the "A" relay, amplifier, this circuit operates as a one-shot when the associated MC-HOLD switch is at MC and as a bistable circuit when the switch is at HOLD. At MC the negative input pulse generates a negative output pulse which energizes the "B" relay momentarily. At HOLD the action of the circuit depends upon which stable state it happens to be in when the pair of input pulses occur. If it is in the non-saturated state, the positive input pulse is ignored and the negative input pulse triggers it to the the saturated state, producing a high output voltage which energizes the "B" relay. If it is in the saturated state, the negative input pulse is ignored while the positive input pulse triggers it to the non-saturated state, producing a low output voltage which de-energizes the "B" relay.

POWER SUPPLIES

General. All power supplies are located on a separate chassis at the rear of the instrument. This chassis is isolated from the rest of the instrument by a dust baffle. The purpose of the power supplies is to produce r-f supply voltages for the saturable reactors; the +300-volt d-c supply is generated only to power the r-f oscillators.

The d-c supply is a conventional transformer-rectifier-filter arrangement using metallic rectifiers. The transformer has two primaries which are connected in parallel for operation on 117V AC and in series for 230-volt operation. The +300V DC output is the plate supply for two vacuum tube oscillators (V201 and V202) which generate carrier supply voltages for the saturable reactors. The oscillators are located on the power supply chassis together with circuitry which regulates the r-f output voltages. The r-f output voltages are reduced by step-down transformers on the hinged chassis before being applied to the reactors as carrier supplies.

1.7 Mcs Carrier Supply. V201 produces a 1.7 Mcs r-f supply at an amplitude of about 150V rms. This output, reduced to 15V rms by a step-down transformer on the hinged panel, is the carrier supply for the decimal counting units. The 150-volt output is also rectified and filtered by other circuitry on the hinged panel to provide two d-c bias supplies: one at -30V DC; the other at -40V DC.

T202 and C205 plus the capacitance of the coaxial connecting cable form a tank circuit for the 1.7Mcs oscillator. The secondary winding of T202 is coupled to the control grid of V201 through C202 and R201. This provides a positive feedback path for sustaining oscillations. The capacitance of C205 has been selected for each individual instrument to fix the oscillator frequency somewhere between 1.69 and 1.71 Mcs. This frequency will not be appreciably disturbed by replacing V201 when that becomes necessary.

The output voltage is regulated by a negative feedback circuit which varies the screen grid potential of V201. The screen grid is connected to the B+ supply through R203 to the plate of the regulator triode V203-B. When V203-B conducts in response to a positive voltage at its grid, the voltage drop across R203 is increased, lowering the screen potential of V201 and reducing the oscillator output voltage.

The grid of V203-B is coupled to a sample of the oscillator output voltage (appearing at Pin 6 of T202) through rectifier CR202, the carrier winding of SR201 and coupling capacitor C203. Due to oper-

ating characteristics which will be described later, the reactance of the carrier winding varies with the amplitude of the oscillator output. When the oscillator output is below the desired voltage level, the carrier winding has so high an impedance that the rectified output is not sufficient to drive V203-B above cut-off. When the oscillator output approaches the proper level, the reactance of the carrier winding drops sharply, the rectified output rises, and V203-B conducts, preventing a further rise in the oscillator output. Should the oscillator output drop slightly, a reverse action takes place: the reactance of the carrier winding increases, the rectified output drops, V203-B conducts less heavily, and the potential on the screen grid of the oscillator rises, thus tending to restore the output to its former level.

Reactor SR201 operates in a rather unusual way. The control winding is functionless, since both terminals are grounded. As the voltage across the carrier winding rises, the Ferristor becomes increasingly saturated due to the influence of carrier current alone. Near full saturation the inductance of the carrier winding is lowered to the point where it becomes nearly equal to the capacitance of C213; that is, the circuit approaches ferro-resonance. At this point, carrier current rises steeply but does not actually "jump" to a new value (as in a bistable circuit) because of resistance R209 in series with the carrier winding. Capacitor C203 determines what fraction of the oscillator output is applied to the carrier winding. This capacitor is adjusted so that the sudden rise in carrier current occurs just before the oscillator output has reached the proper level.

10.2Mcs Carrier Supply. V201 generates a 10.2 Mcs r-f supply with an amplitude of about 85 volts rms. This supply is fed to a step-down transformer on the hinged panel which produces two outputs: one at 34 volts rms, a second at 22 volts rms. The 34-volt output is the carrier supply for all gated one-shots and the reset one-shot. The 22-volt output is the carrier supply for the input amplifier, the current discriminator and both coincidence channels.

The 10.2Mcs oscillator circuit is similar to the 1.7Mcs oscillator. The value of C210 has been chosen separately for each instrument in order to fix the frequency at 10.2Mcs ±0.1Mcs. Tube replacement will not ordinarily cause enough frequency shift to necessitate re-tuning.

The voltage regulating circuit operates in essentially the same way as that regulating the 1.7Mcs oscillator. The only appreciable difference is that the control winding of SR202 is coupled to a rectified sample of the oscillator output voltage and, through feedback resistor R214 to the rectified output of the reactor itself. With this arrangement, current in the control winding aids carrier current in saturating the reactor as carrier voltage rises. Another minor difference is CR204, a varistor which takes the place of a resistor in the triode grid circuit. Due to non-linear resistance characteristics, this element provides more efficient d-c coupling from cathode of CR205 to grid of V203-A.

Servicing

ROUTINE MAINTENANCE

Test the tubes weekly using the TEST-OPERATE switch as directed on page 8. If input signal amplitude is less than 2 volts peak-to-peak, it may be desirable to re-adjust the INPUT LEVEL ADJ control periodically to compensate for possible drift. Directions for adjusting this control appear on page 5. No further maintenance is necessary.

TROUBLESHOOTING

General Procedure

When the instrument fails to operate properly consult the "Table of Common Troubles" first. If this fails to disclose the source of trouble check the r-f power supplies next, because inadequate carrier voltages may produce a bewildering variety of symptoms. Once the supplies are known to be adequate, follow the localizing procedure to trace the defect to a particular magnetic circuit. Then, search for the defect in that circuit. Test points mentioned below are labeled on both the schematic diagrams and the illustrations showing the location of various parts.

Table Of Common Troubles

Symptom. Red front-panel indicator fails to light.

Probable Cause. Fuse F201 or F202 is open. See "Troubleshooting, Checking Power Supplies, Line Power".

Symptom. Red front-panel indicator lights, but no digits on the lucite panels are illuminated.

Probable Cause. 1.7 Mcs carrier supply is inadequate due to defective oscillator tube (V201) or to failure of +300-volt supply.

Symptom. Digits on lucite panel are illuminated, but "units"DCU will not count.

Probable Cause.

1. Input signal amplitude too small.
2. INPUT LEVEL ADJUST positioned improperly.
3. 10.2Mcs carrier supply is inadequate due to defective oscillator tube V202.

Symptom. Instrument counts correctly but one of the output relays fails to close when preset count is reached.

Probable Cause. Coincidence pre-amplifier in this output channel has drifted. Re-adjust bias magnets as described under "Trouble Localizing Procedure, Checking the A Coincidence Channel".

Symptom. Other symptoms of faulty operation due to poorly regulated carrier supply voltages. These symptoms may include failure of one or more DCU's to count, unusually bright neon lights behind the lucite panels or failure of one of the output relays

Probable Cause. Regulator tube (V203) defective.

Checking Power Supplies

Line Power. The pilot light on the front panel indicates that power is reaching the main power transformer. If this indicator fails to light when not burned out, one of the line fuses mounted on the power supply is probably open for some reason. Check to see that the fuses are the proper value for the line voltage applied (2 amps for 117 volts, 1 amp for 222 volts). If operating from a 222-volt line, make sure that 117-volt plug has not been inserted in J203. Finally, check the d-c power supply for short circuits to ground.

300-volt D-C Supply. For proper operation, this supply voltage should lie somewhere between +290 and +350 volts. It can be measured at the output of filter capacitor C201. If the voltage there falls outside the permissible range, check to see that P202 has been inserted in accordance with the directions on page 4. If P202 is positioned correctly search for trouble in rectifier CR201 or filter capacitor C201.

Carrier Supplies. These supplies are generated by r-f oscillators. It is not likely that any will be so far off-frequency as to impair operation, but it is possible that output amplitude will be insufficient. The amplitude values appearing below were obtained with a Hewlett Packard VTVM Model 410B, which has the following characteristics:

(a) Deflection proportional to peak amplitude.
(b) Calibrated in rms value.
(c) Provided with vacuum tube diode probe with input capacitance less the 2$\mu\mu$f and input resistance above 10 megohms.

1.7 Mcs Carrier Supply. Measure the r-f voltage with respect to ground at test points 27 and 28. Readings at both points should be between 14 and 15v rms. If voltages do not fall within tolerances, adjust C203 until the proper level appears. If adjustment fails to correct the condition, check the 1.7 Mcs regulated oscillator with special attention to tubes V201, V203B and crystal diode CR202. Regulation is dependent on the -30VDC bias supply; therefore, check this supply also as described below. The r-f frequency of this supply is somewhat critical; it should not fall outside 1.69 to 1.71 Mcs.

10.2 Mcs Carrier Supply. Measure the r-f voltage with respect to ground at test point 26. The reading here should be 34v ±2v rms. If the voltage is too high or too low, adjust C204. If adjustment fails to create the proper level, check the 10.2 Mcs regulated oscillator. Components most likely to fail are tubes V202 and V203A and crystal diode CR205. Regulation is dependent on the -30VDC bias supply. The r-f frequency of this supply is not critical.

-30VDC Bias Supply. This supply is generated by rectifying the 1.7 Mcs r-f supply voltage; however, the d-c output level will be sufficiently stable even if the r-f supply is poorly regulated for some reason. Measure the d-c voltage at test point 24. Voltage should be -30VDC±5VDC. If voltage falls outside tolerances check crystal diodes CR130 and CR131.

-40VDC Bias Supply. Measure the d-c voltage at test point 25. Voltage should be -40VDC ±1VDC. If not within tolerances check crystal diodes CR132 and CR133.

TROUBLE LOCALIZING PROCEDURE

Provided all r-f and d-c supplies are known to be adequate, a fault in the remaining circuitry can be localized by fairly straightforward signal tracing techniques. Referring to the block diagram, notice that the instrument may be divided into three relatively independent sections:
First, the input circuitry and the chain of decimal counting units.
Second, the "A" coincident channel consisting of the "A" preamplifier and amplifier, the "A" relay amplifier and the "A" relay.
Third, The "B" coincidence channel consisting of elements corresponding to those in the "A" channel plus the reset one-shot.

Checking the Input Circuitry and DCU's. With an input signal applied, place the AUTO-MAN switch at MAN. If the DCU's do not count accurately and continuously, there is a defect somewhere in this part of the circuitry. To make a low frequency check, turn the INPUT LEVEL ADJ control from one extreme to the other and back again with no input signal. Each back-and-forth rotation of this control should score one count on the "units" DCU. Press the manual RESET button; all DCU's should return to a registered count of zero; those which don't are probably defective.

Test points 1 thru 14 are located in sequence along the signal path. To localize a defect, observe the waveforms at these test points in order. Beyond test point 10 the pulse frequency may be too low to observe conveniently on an oscilloscope. In this case the visible counting action of the DCU's will probably provide a clue to the defective stage.

Checking the A Coincidence Channel. Test "A" output relay (K102) for proper closure (MC and HOLD) as the instrument counts up to and through count A. This may be done by placing an ohmmeter across the normally-open contacts. If the relay fails to close upon coincidence, trace the coincidence signal, observing test points 15 thru 18, until faulty signal appears.

A poor signal at test points 15 and 16 may be due to improperly positioned bias magnets on reactors SR110 and SR111. Adjust these magnets as follows:

1. Place the A channel at coincidence; that is, set the preset count switches to match whatever number the instrument is registering.
2. Loosen the screw holding the bias magnet on SR110. Rotate the magnet through 360 degrees while metering the d-c voltage with respect to ground at test point 15. Position the magnet at the point where the d-c voltage is maximum, then rotate it slowly in either direction until the voltage falls to -10v.
3. Perform step 2 on SR111 while metering the voltage at test point 16.
4. There is interaction between SR110 and SR111; therefore, repeat steps 2 and 3 as often as necessary until the voltage difference between the test points is not more than 0.2 volts. It's best to use a voltmeter with neither terminal grounded and to measure the potential difference between test points directly.

To make sure the coincidence channel will receive an adequate signal from the DCU's at all possible preset counts, test relay closure for the following preset counts: 111, 111; 222, 222; 333, 333; etc thru 999, 999; 000, 000.

Checking the B Coincidence Channel. Place the AUTO-MAN switch at MAN then check this channel in the same way as the "A" channel, testing the "B" output relay (K101). Observe test points 19 thru 23 if necessary to locate and repair trouble. After the channel is known to operate all right with the switch at MAN, test it again with the switch at AUTO.

Interaction between Circuits. Under some conditions a defective circuit may load the carrier supplies so heavily that other circuits will not receive sufficient carrier voltage to operate properly. This is most likely to occur at times when both the "A" and "B" relays are energized.

Troubleshooting a Particular Circuit

D-C Test. One way to test a magnetic circuit is to measure the demodulated output voltage. The d-c output level should be 2 to 10 volts when the Ferristor is unsaturated and 20 to 40 volts when it is saturated.

Defective diodes are the most common cause of faulty operation in circuits using Ferristors. A diode can be tested by placing it in a circuit known to be operative or by replacing it with another diode known to be in good condition. Some type 1N34A diodes in this instrument have been especially selected for desirable characteristics. These diodes are identified by a dab of red or green paint on the glass. Those marked by a red dot have been designated 1N34AR, those bearing a green dot, 1N34AG. Always replace a diode with one bearing the same color code.

Identifying Terminals on a Ferristor. Ferristor terminals are identified by small embossed numbers on the under side of the capsule. However, when a Ferristor is mounted on a terminal board, these numbers may not be visible. In this case figure 9 will help identify hidden terminals.

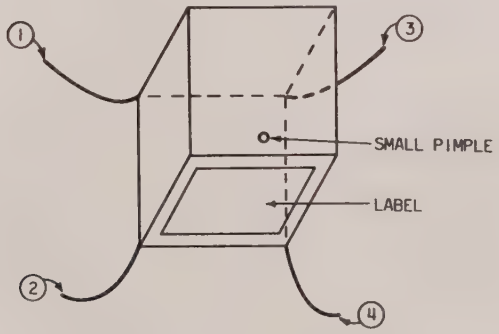
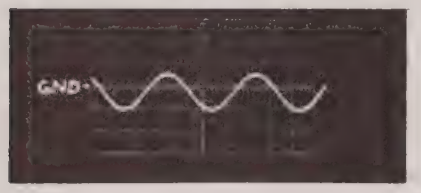


FIGURE 14.

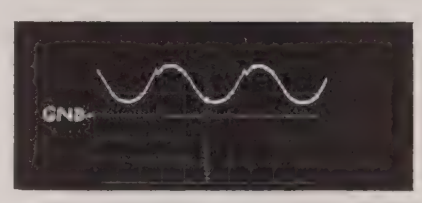
SKETCH SHOWING POSITION OF FERRISTOR TERMINALS RELATIVE TO VISIBLE FEATURES OF CAPSULE.

TYPICAL WAVEFORMS

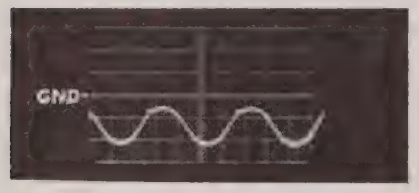
The waveforms which appear on the following pages were obtained with a Tektronic 531 oscilloscope equipped with type 53C pre-amplifiers. The circled numbers near the pictures refer to test points so labeled on the schematic diagrams and on the pictures showing the location of parts. When troubleshooting with an oscilloscope, ground the scope to the chassis somewhere near the test point. All test points are listed below. In cases where an oscilloscope presentation is impossible or unnecessary, the signal is described in some other way.



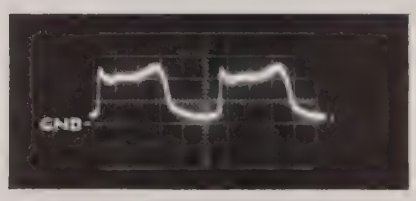
(0) 5kcs signal at input terminal. (5v/cm, 50μsec/cm).



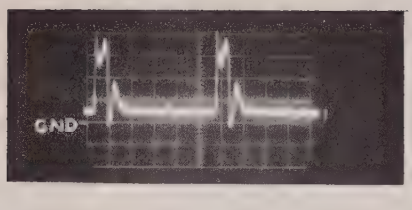
(2) Output of second half of balanced input amplifier. (10v/cm, 50μsec/cm).



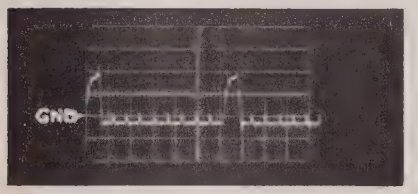
(1) Output of first half of balanced input amplifier. (10v/cm, 50μsec/cm). Small "notches", the reflected effect of succeeding trigger circuit, show points on input waveform where triggering occurs. This waveform must be in phase with that at test point 2.



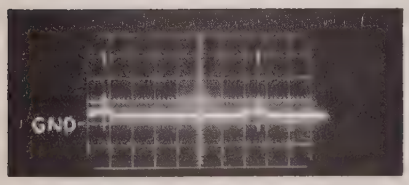
(3) Output of trigger circuit, a current discriminator. (10v/cm, 20μsec/cm). Note that the output remains at the higher voltage level approximately the same length of time that it stays at the lower voltage level; that is, that the positive square wave is about as wide as the negative square wave. This indicates that the INPUT LEVEL ADJUST is properly positioned for dependable triggering. The positive transients drive the first one-shot.



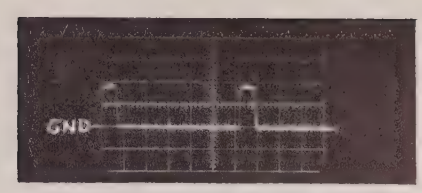
(4) Two output pulses from the first one-shot. (10v/cm, 20μsec/cm). Pulse should have a double peak and fast rise time as shown.



(5) Gate signal to second one-shot. (5v/cm, 200μsec/cm) Gate is open during the period of the large positive pulses. Smaller pulses are caused by input pulses which do not pass thru gate. Notice that gate opens after every ninth pulse and closes after every tenth pulse.



(6) Output of second one-shot. (10v/cm, 200μsec/cm) The large positive pulses drive the "tens" DCU and the third one-shot. The time interval between these pulses should be ten times the pulse interval at test point 4. Outputs of all succeeding one-shots have a similar waveform.

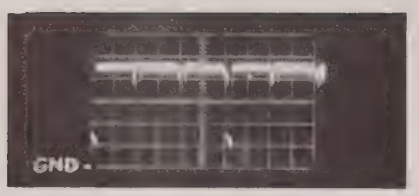


(7) Gate signal to third one-shot. (10v/cm, 2millisec/-cm). Gate open during period of positive pulse, which approaches a square wave at this frequency. Gate signals to all succeeding one-shots are similar to this waveform.

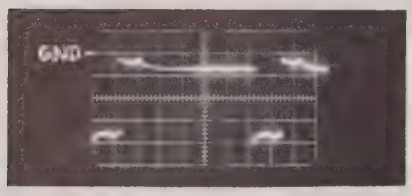
(8) (10) (12) and (14)
Output signals of third, fourth, fifth and sixth one-shots. All essentially the same as waveform at test point 6 except time between pulses increases by multiples of ten.

(9) (11) and (13)
Gate signals to third, fourth, fifth and sixth one-shots. All essentially the same as waveform at test point 7 except time between open gate conditions increases by multiples of ten.

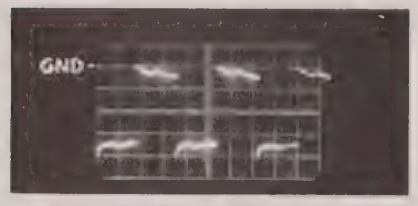
(15) and (16)
Double-ended output of "A" coincidence pre-amplifier. At coincidence (that is, when the DCU's are registering preset count A) the potential difference between these two points should be 0.2 volts or less. At all other times the voltage difference between them should be 2 volts or more. Because there is a d-c voltage at both points, it may be convenient to measure both with respect to ground and to compare readings.



(17) Output of "A" coincidence amplifier (5v/cm, 1500μsec/cm) 15-volt negative pulses occur at coincidence. This signal is coupled to the "A" pulse output terminal as well as to the relay amplifier. Width of pulse is equal to period of signal at input terminal.

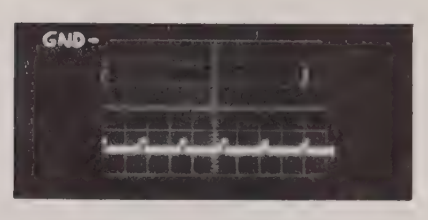


(18) Output of "A" relay amplifier with MC-HOLD switch at MC. (20v/cm, 20millisec/cm). Relay becomes energized for duration of 24-millisecond pulse.



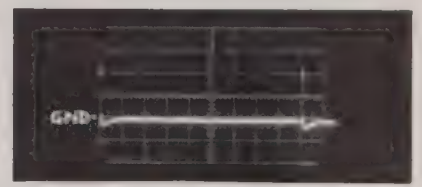
(18) Output of "A" relay amplifier with MC-HOLD switch at HOLD. (20v/cm, 20millisec/cm). Output level near ground is maintained until count A. 60-volt output level, which energizes relay, persists until reset.

(19) and (20) Double-ended output of "B" coincidence pre-amplifier. Signal here has same characteristics as that at test points 15 and 16 except that coincidence occurs at preset count B.

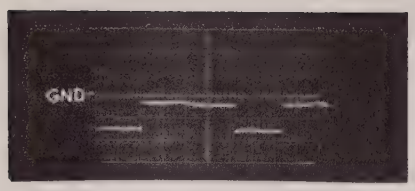


(21) Output of "B" coincidence amplifier. (5v/cm, millisec/cm). 15-volt pulses occur at coincidence.

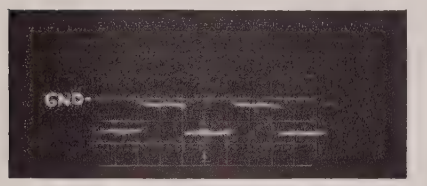
(21) Output of "B" coincidence amplifier showing coincidence pulse expanded. (5v/cm, 100μsec/cm).



(22) Output of reset one-shot. (10v/cm, 1millisec/cm). 25-volt pulse occurs at "B" coincidence.

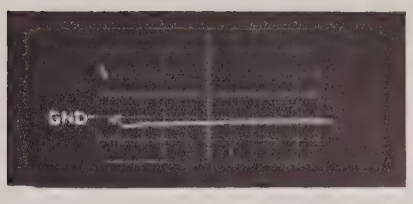


(23) Output of "B" relay amplifier with MC-HOLD switch at MC (50v/cm, 20millisec/cm). Relay becomes energized for approximately 40millisec.

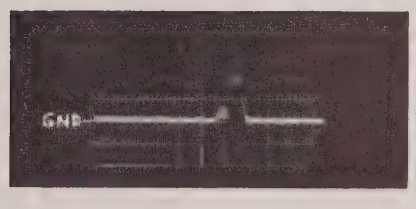


(23) Output of "B" relay amplifier with MC-HOLD switch at HOLD. (50v/cm, 20millsec/cm). Output level switchs back and forth, energizing and de-energizing relay, as successive "B" coincidence points are reached.

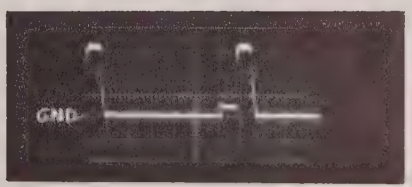
(24) thru (28)
These are points at which r-f and d-c supply voltages appear. See "Checking Power Supplies" for amplitude and frequency characteristics.



(22) Output of reset one-shot showing coincidence pulse expanded. (10v/cm, 100μsec/cm).



(29) Gate-actuating output of "units" DCU. (10v/cm, 2millisec/cm). High output level occurs while DCU is registering nine. R-F superimposed on high output level is normal.



(30) Gate-actuating output of "tens" DCU. (10v/cm, 2millisec/cm).

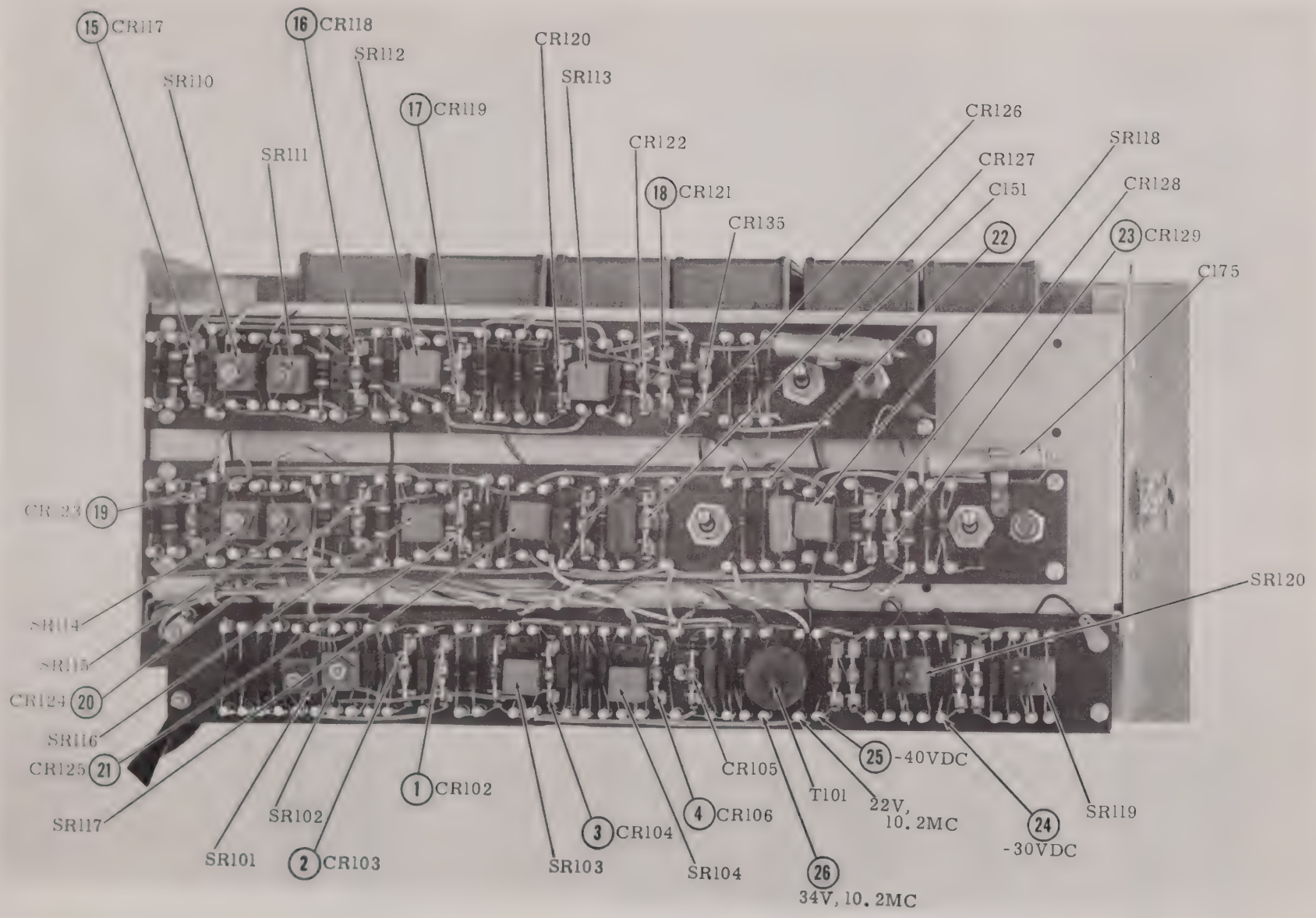


FIGURE 5. PARTS LOCATION. UPPER TERMINAL BOARD IS "A" COINCIDENCE CHANNEL MIDDLE STRIP IS "B" COINCIDENCE CHANNEL . LOWER STRIP IS INPUT CIRCUIT AND D-C BIAS SUPPLIES. THIS IS A VIEW OF A MODEL 5846 FROM PRODUCTION LOT 3. LATER PRODUCTION LOTS MAY DIFFER IN MINOR DETAILS.

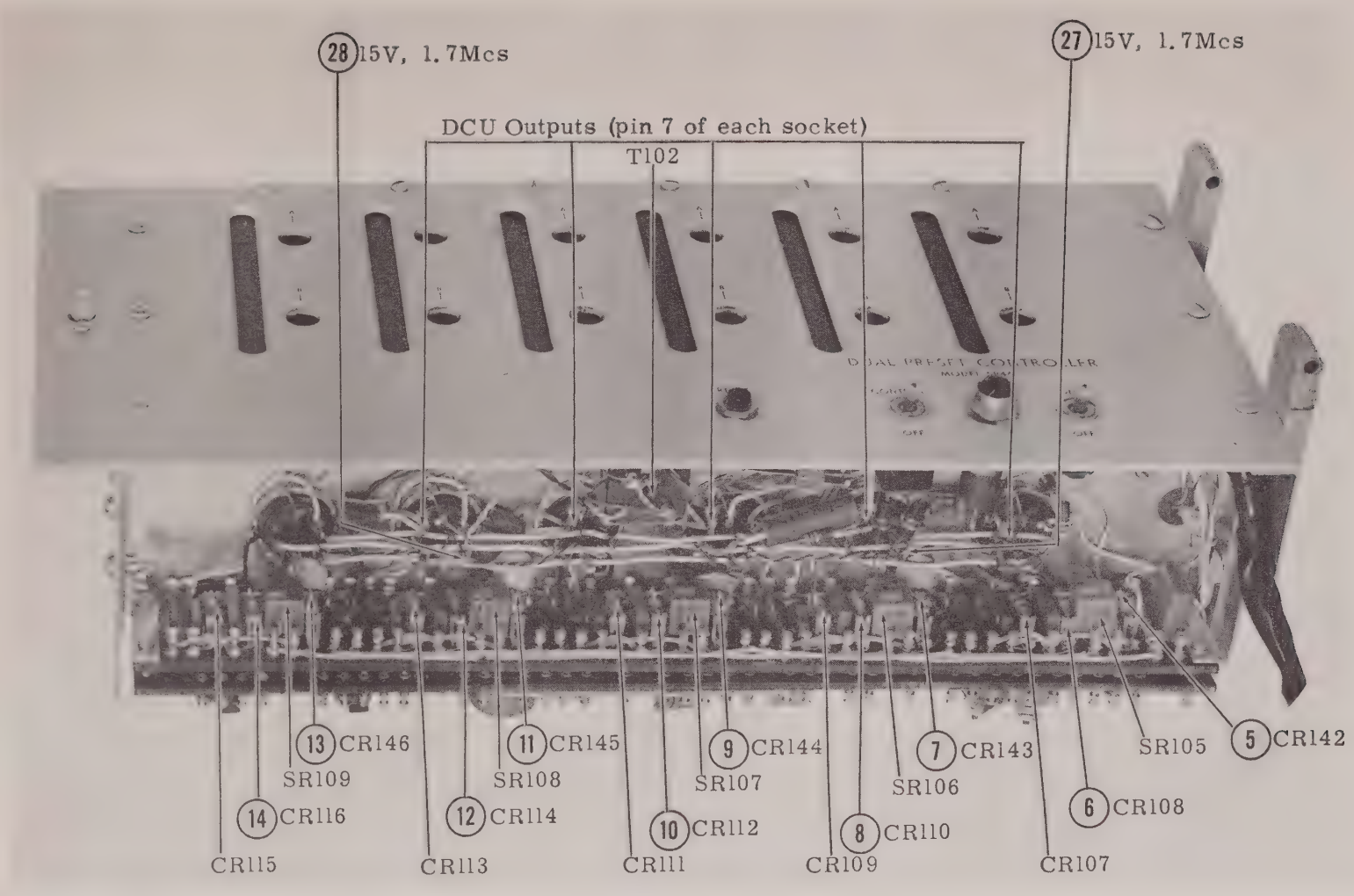


FIGURE 6. PARTS LOCATION, ONE-SHOT GATE CIRCUITS. THIS IS A VIEW OF A MODEL 5846 FROM PRODUCTION LOT 3. LATER PRODUCTION LOTS MAY DIFFER IN MINOR DETAILS.

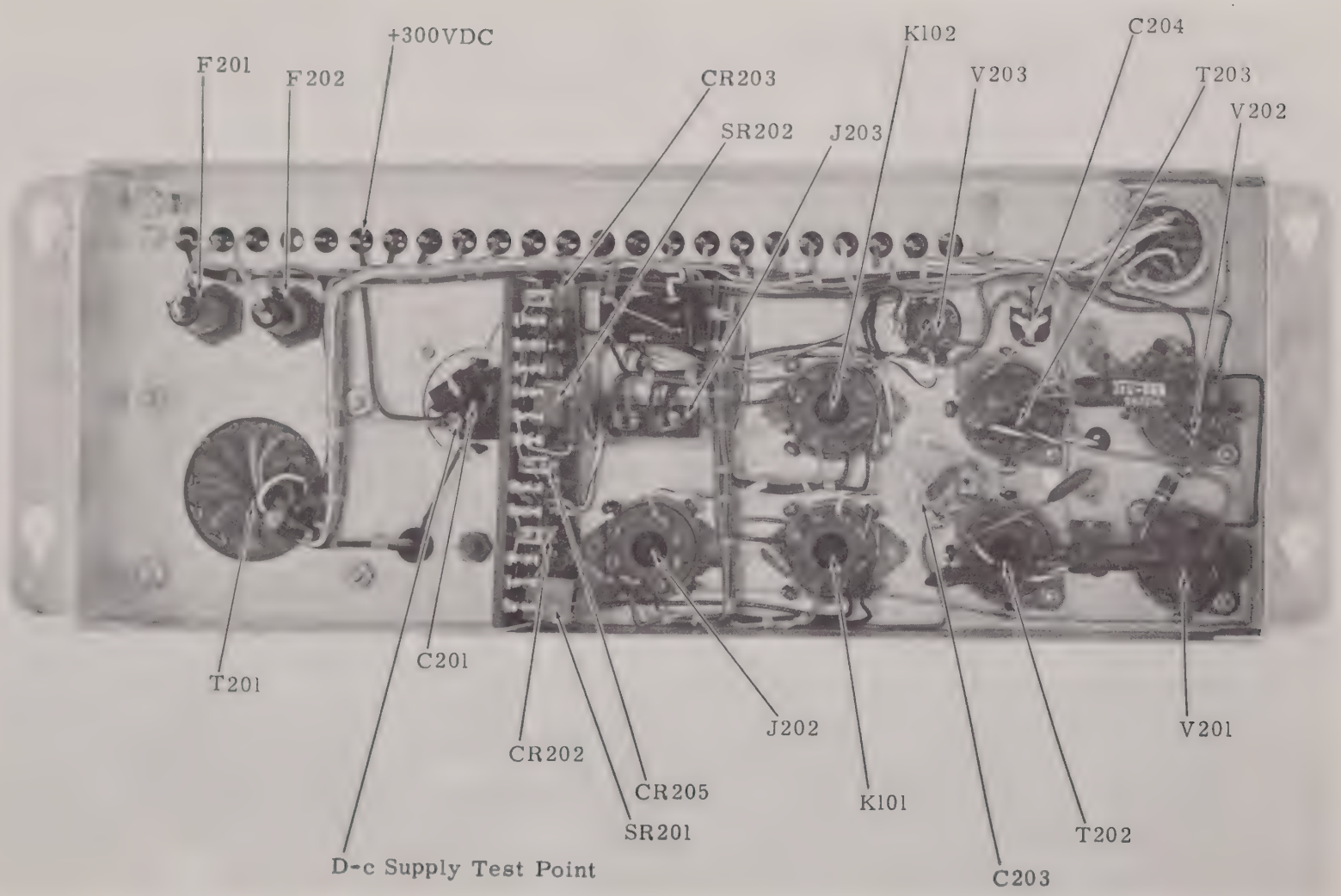


FIGURE 7. BOTTOM VIEW OF POWER SUPPLY CHASSIS. THIS IS A VIEW OF A MODEL 5846 FROM PRODUCTION LOT 3. LATER PRODUCTION LOTS MAY DIFFER IN MINOR DETAILS.

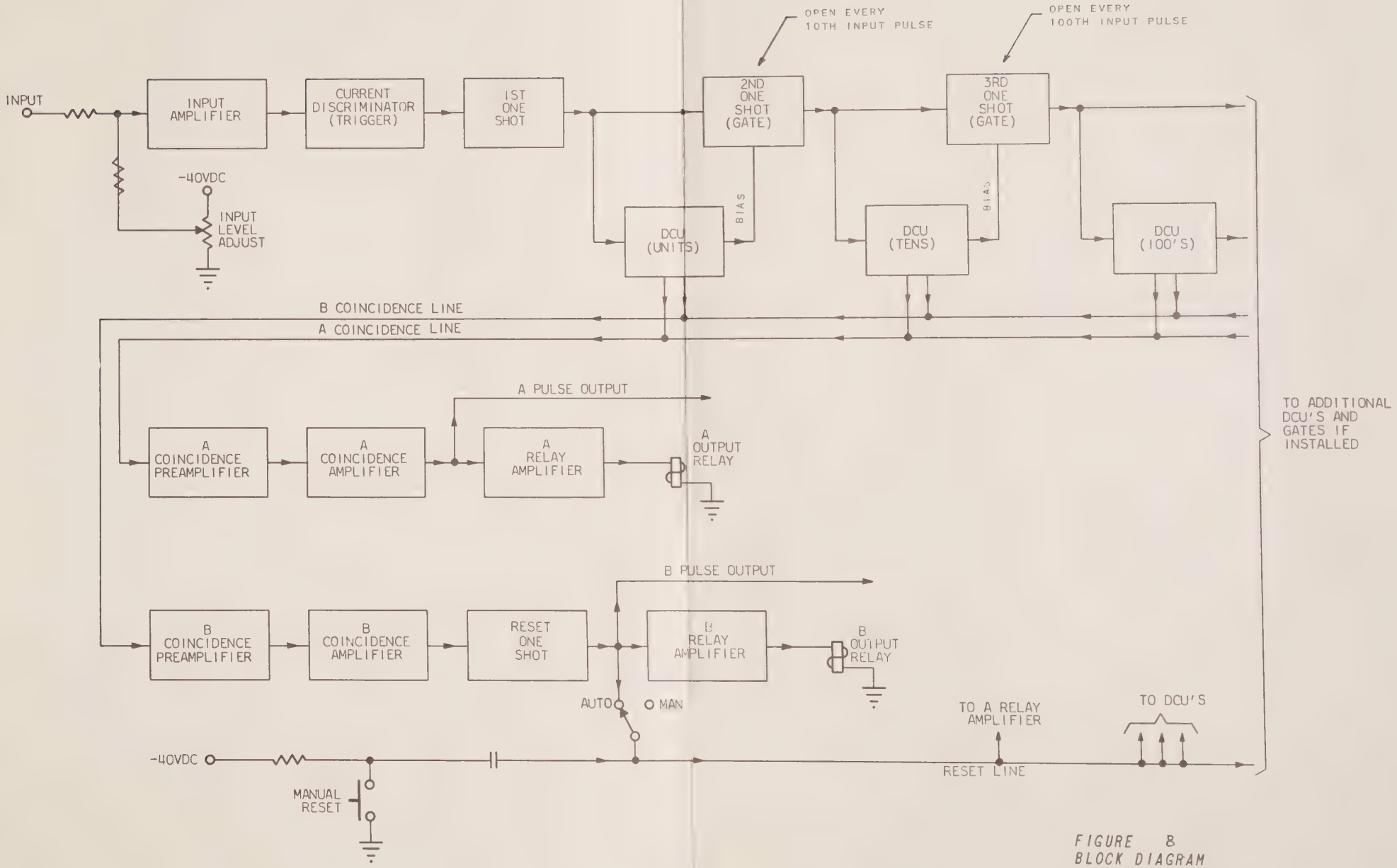
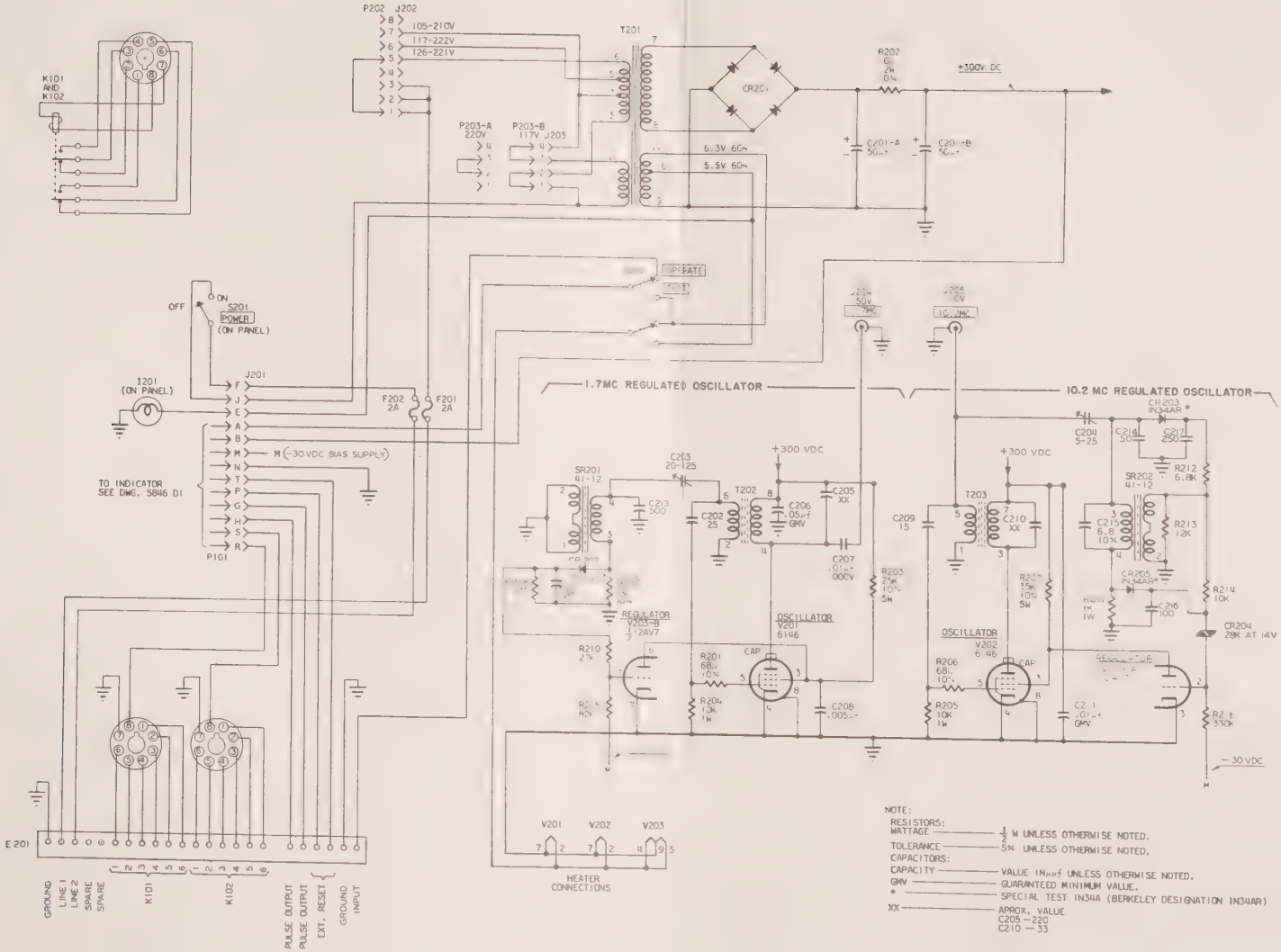
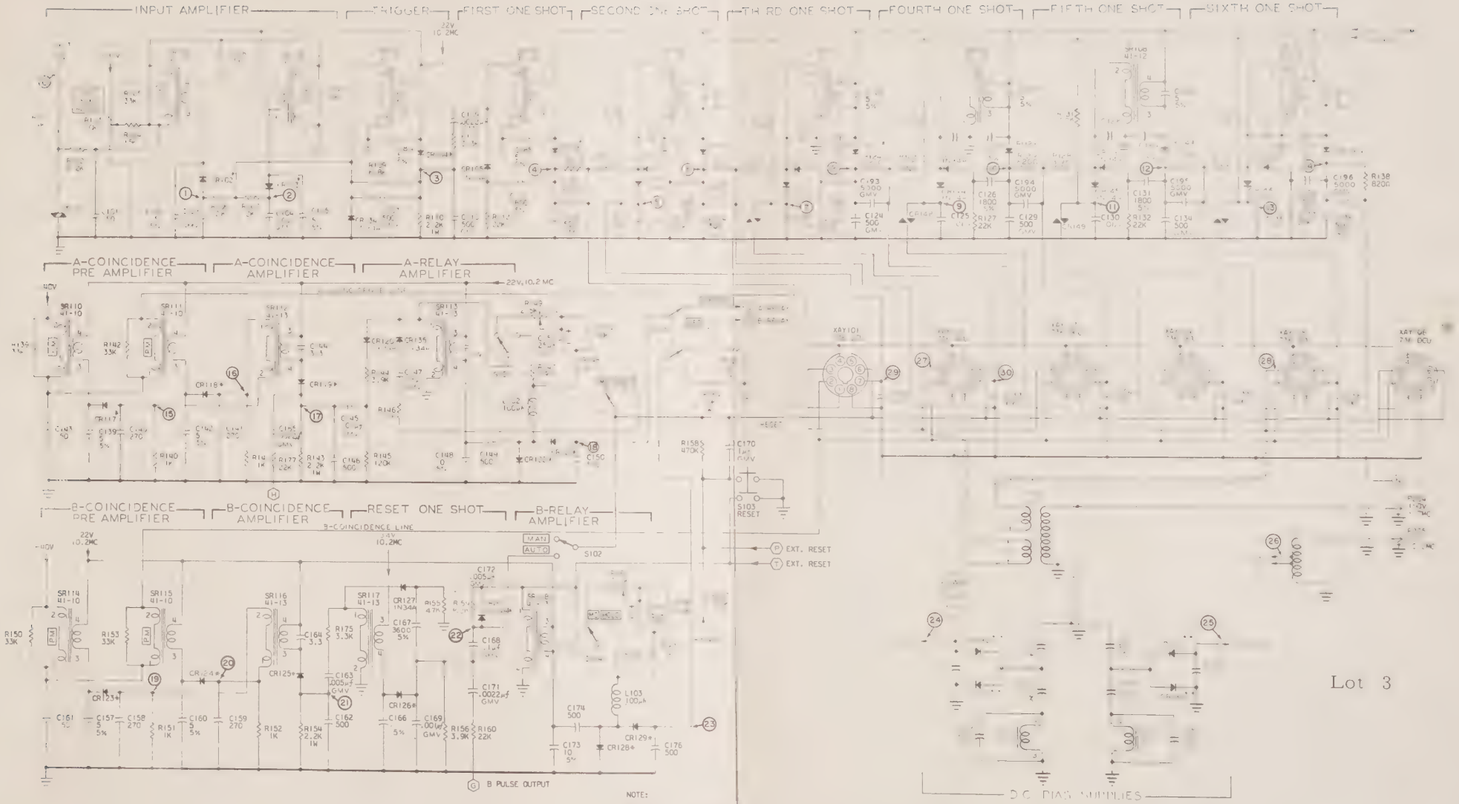


FIGURE 8
BLOCK DIAGRAM
MODEL 5840 SERIES



12 May 58

SCHEMATIC DIAGRAM
D-C AND R-F POWER SUPPLIES
MODEL 5840 SERIES
DWG. NO. 5846D2



Lot 3

SCHEMATIC DIAGRAM
ENTIRE EQUIPMENT EXCEPT
POWER SUPPLIES
MODEL 5840 SERIES
DWG. NO. 5846D1

ELEMENTARY CIRCUITS USING SATURABLE REACTORS

THE BASIC AMPLIFIER

Figure 1 is a schematic diagram of a magnetic circuit which is comparable to a vacuum tube amplifier. The magnetic component itself consists of two windings of fine wire on a tiny iron core, all encased in resin. Its basic characteristics arise from the fact that the small core can be saturated by minute currents in either winding. For this reason it is called a "saturable reactor"--abbreviated "SR". With no current the carrier winding has the relatively high inductance of an iron-core inductor. But, when the sum of the currents in both windings increases beyond a certain point, the core saturates and the inductance of the carrier winding falls greatly. When operated as an amplifier, current in the control winding is used to vary the inductance of the carrier winding. If the carrier winding is energized by a carrier supply (an a-c voltage source), its changing inductance will cause changes in the carrier current flowing in it. Since the carrier current variations are much larger than the control current variations, the SR produces amplification. In Figure 1 the a-c carrier current flows through the carrier winding and C1. The voltage developed across C1 is the carrier, modulated in accordance with control current variations. This signal is rectified and filtered to produce a demodulated output.

Notice that this circuit is roughly analogous to a vacuum tube amplifier. Control current corresponds to control grid voltage; carrier supply voltage, to B+ supply; carrier current, to plate current; and load impedance, to plate load. The main differences are that the controlling quantity is a current rather than a potential and that a carrier frequency must be introduced, modulated and finally removed.

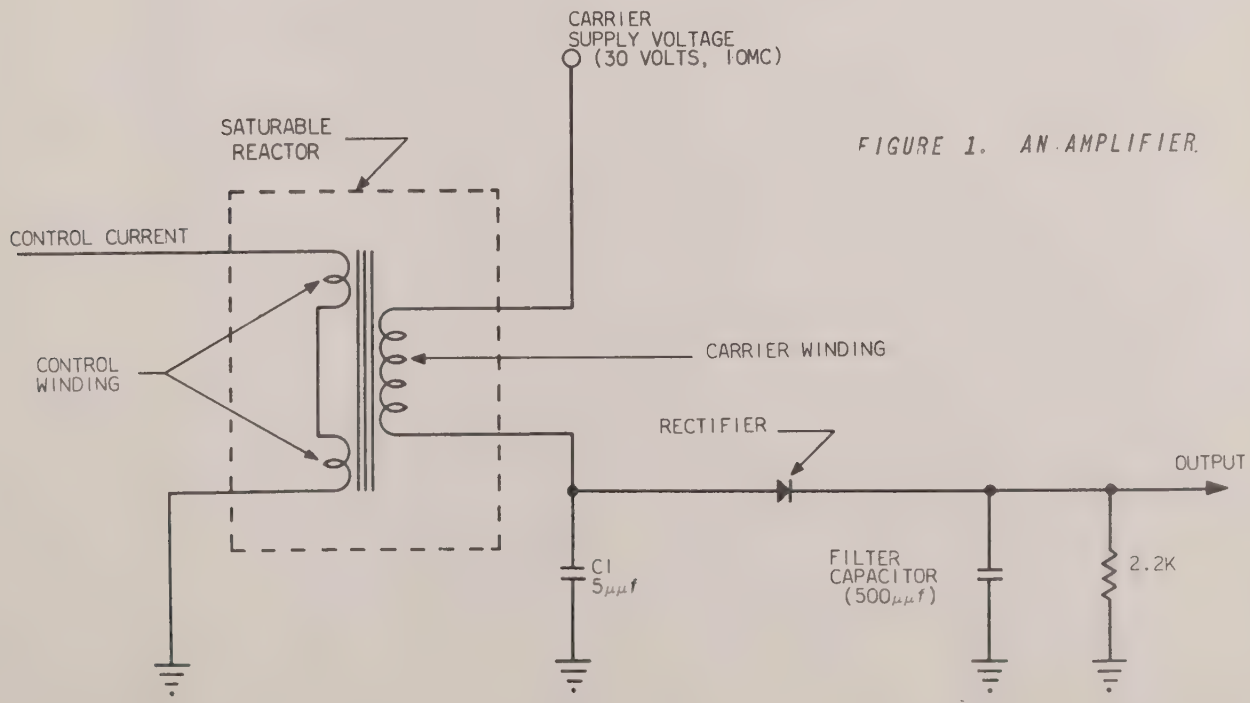


FIGURE 1. AN AMPLIFIER.

The transfer characteristics of this amplifier are diagramed in Figure 2. This figure shows how carrier winding inductance and output voltage vary with input current. The inductance is nearly constant from zero current until saturation begins. This range will be called the "non-saturated" region. From the beginning of saturation until the reactor is fully saturated the inductance falls rapidly. This will be called the region of "partial saturation." Beyond full saturation the inductance stays nearly constant again

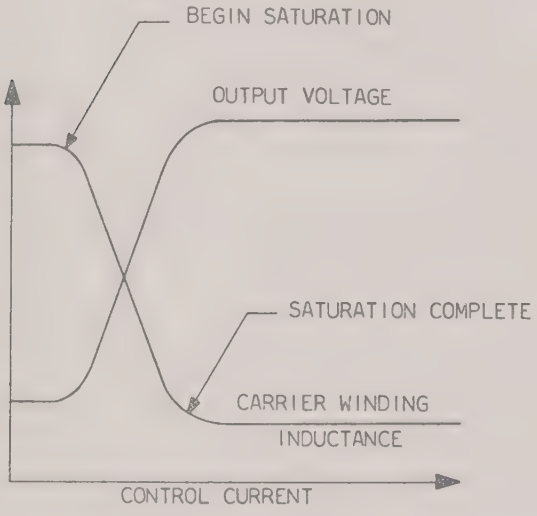


FIGURE 2. AMPLIFIER CHARACTERISTICS

at a lower value. This will be called simply the "saturated" region. Notice that the transfer-characterisitc curve (output voltage VS control current) is analogous to that of a vacuum tube. The point at which saturation begins corresponds to cutoff and the full saturation point corresponds to plate saturation. The gain is apprec - iable only when the control current varies within the region of partial saturation.

A CURRENT DISCRIMINATOR

Figure 3 shows an amplifier circuit which has been converted to a current discriminator by adding positive resistive feedback. This circuit is the magnetic equivalent of the well-known Schmitt trigger vacuum tube circuit. The output voltage E_o draws current through the control winding and feedback resistor in a direction that reinforces the input current. As the input current rises from zero to the point where saturation begins, the output voltage remains almost constant. When the reactor begins to saturate, the gain from input to output rises sharply. At a certain point the feedback loop gain becomes greater than one and the control current and output voltage increase rapidly in a regenerative circuit until the reactor is fully saturated. At this point the gain from input to output decreases again to nearly zero and further increases in input current have no effect. When the input current decreases to a value slightly lower than that at which sudden saturation occurred, the total current in the control winding becomes too low to maintain saturation. At this point the output voltage begins to drop, and a reverse regenerative action returns the circuit to the original unsaturated state. Due to this action the circuit switches rapidly back and forth from one to another of two comparatively constant states as the input current rises and falls. Because the state it assumes depends only upon whether the input current is above or below a certain value, it is called a "current discriminator". The difference between the input current value at which the reactor switches from non-saturation to saturation and the lower value at which it switches back from saturation to non-saturation is called the hysteresis of the circuit. In electronic counters this circuit is used mainly to generate sharp pulses from slowly varying waveforms.

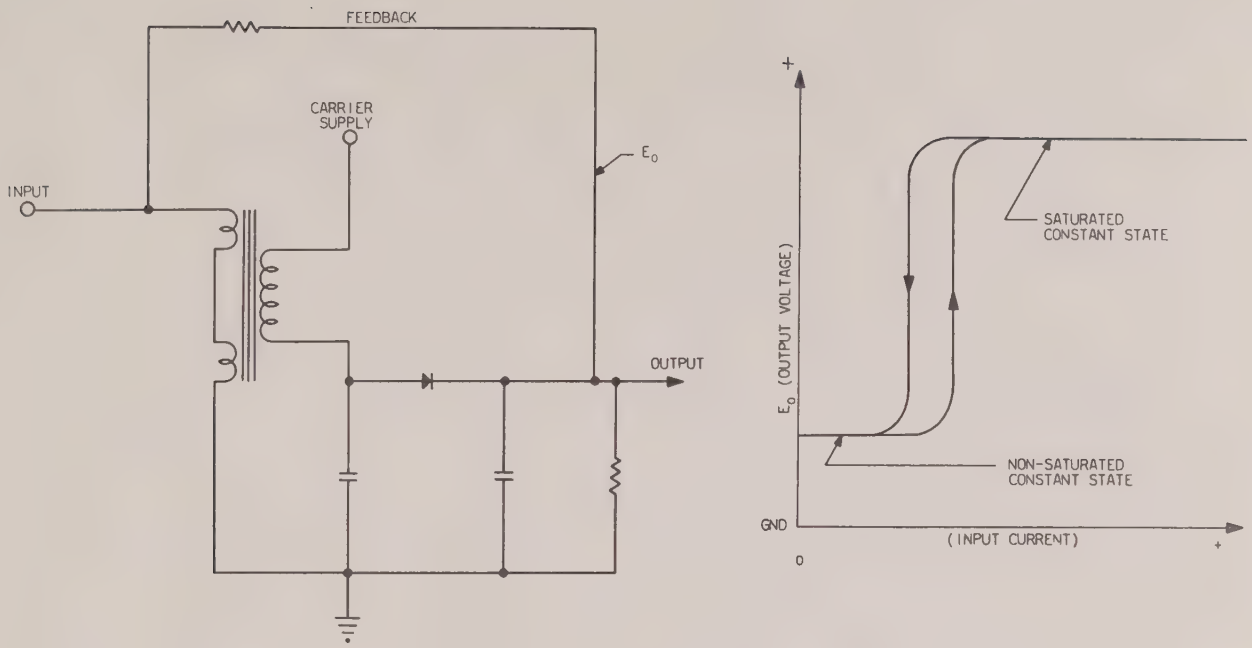


FIGURE 3. A CURRENT DISCRIMINATOR

A CIRCUIT BISTABLE AT ZERO INPUT

If the value of the feedback resistor in the current discriminator described above is lowered, the hysteresis of the circuit will increase until the transfer characteristic curve assumes the shape shown in Figure 4. This happens because the feedback current in the saturated state becomes so great that it will hold the reactor saturated without the aid of any input current, and even when some input current is "bucking" the feedback current in the control winding. In this discussion "positive" input current means current in a direction which aids feedback and "negative" input current means current which "bucks" feedback. Notice that with no input current the circuit is stable in either the saturated or non-saturated state. Due to this characteristic the circuit may be used as a sort of "flip-flop". Starting at zero input current and non-saturation, a pulse of positive current will switch the circuit to saturation, where it will remain when the input returns to zero. With the circuit in the saturated state a pulse of negative input current will switch it back to the non-saturated state, where it will stabilize when the input again returns to zero.

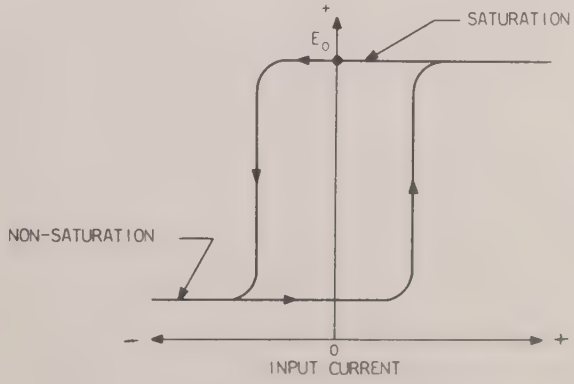


FIGURE 4

A ONE-SHOT MULTIVIBRATOR

Figure 5 shows an amplifier circuit converted to a one-shot multivibrator by adding an R-C feedback loop. The input current to this circuit is usually a series of pulses--in this case, positive pulses. The rising current of each pulse produces a voltage rise at the output. This places a positive potential on the output side of C_f, causing the other side to draw current through R_f and the control winding. If the input pulse has enough amplitude to reach the region of partial saturation, the feedback loop gain will become momentarily greater than one and the conrol current and output voltage will increase rapidly in a regenerative circuit until the reactor is fully saturated. At this point E_o stops rising and the control current decreases as C_f approaches a full charge. When the control current re-enters the region of partial saturation a reverse regenerative action rapidly returns the reactor to the non-saturated state. The duration of full saturation depends upon the R-C time constant of the feedback loop, becoming longer as the time constant lengthens. This circuit is used mainly to produce uniform amplified pulses with steeper leading and trailing edges. It will also function as a pulse gate if a bias current is used to raise and lower the d-c level which the control current assumes in the absence of input pulses. With a high d-c level, input pulses of correct amplitude reach the region of partial saturation and output pulses are produced. In this condition the gate is "open". With a low d-c level, input pulses do not reach partial saturation, no output pulses occur and the gate is effectively "closed".

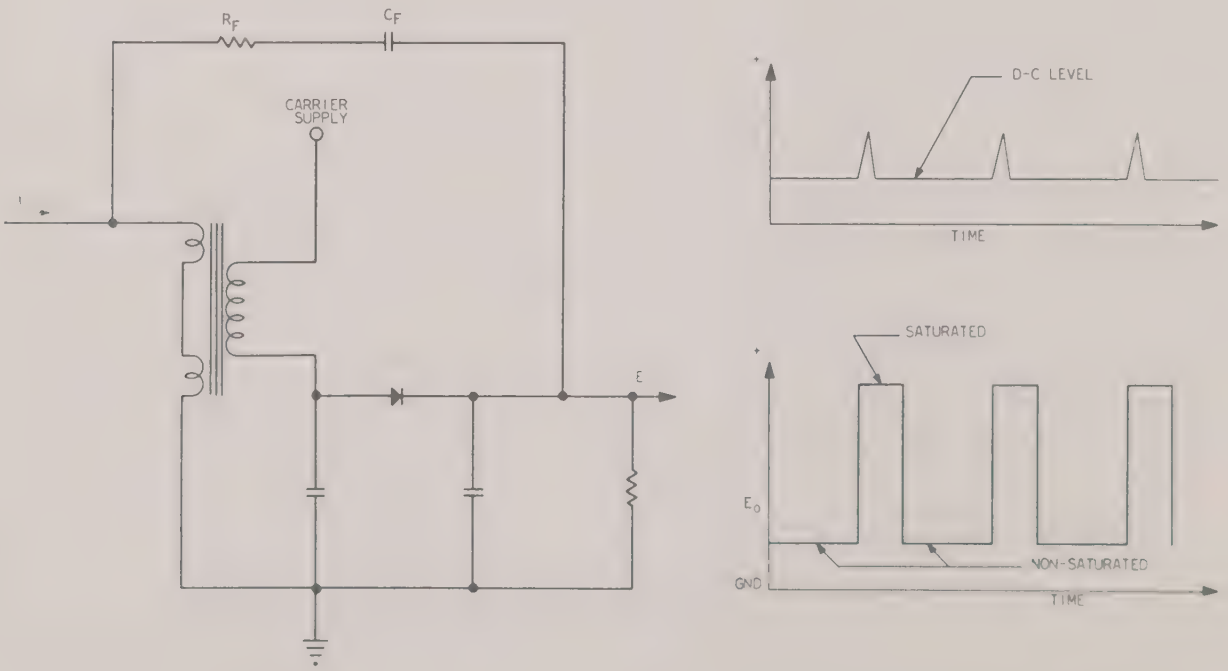


FIGURE 5. ONE-SHOT MULTIVIBRATOR

The amplifier circuits described on the previous pages are built so that the carrier does not have an appreciable saturating effect. This is done by deliberately keeping carrier current comparatively low. However, heavier carrier current can saturate the reactor without the aid of any control current. Consider the circuit shown in Figure 6, C1 has a value such that its capacitive reactance equals the inductive reactance of the carrier winding (L1) at some point near full saturation. At this point the carrier winding circuit becomes series resonant and its total im-

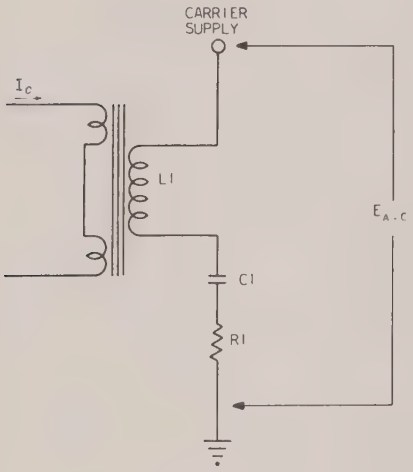


FIGURE 6.

pedance becomes so small that enough carrier current flows to saturate the reactor in the absence of control current.

Figure 7 shows how the reactance of the carrier winding circuit varies with carrier current (I_{a-c}) when there is no control current (I_c) whatever. Current and reactance are interdependent. Up to the resonant point an increase in current causes a decrease in reactance which causes a further increase in current producing another decrease in reactance, etc. This mutual reinforcement creates the possibility of a "run-away" regenerative action. When E_{a-c} is initially applied, the current rises and the reactance falls to point B. At this point the circuit stabilizes because increasing current does not cause the reactance to fall rapidly enough to create a "run-away" effect. However, if the reactance is lowered to point C by some device, "run-away" regeneration will occur and the carrier current will increase through the resonant point and beyond. At point F the circuit will stabilize again since the reactance (now capacitive) is increasing with further increases in I_{a-c}. Thus, the circuit has two stable states: a non-saturated state at point B and a saturated state at point F. The circuit may be triggered from non-saturation to saturation by any action which will partially saturate the reactor enough to lower the reactance to point C. To switch the circuit back to the non-saturated state the carrier voltage must be lowered enough so that too little current will flow to maintain saturation even at the resonant point.

Figure 8 shows the relationship between the voltage across the carrier winding circuit (E_{a-c}) and the current flowing (I_{a-c}) when the load resistance (R1) is taken into account. This diagram illustrates the bistable characteristics of the circuit well. Note that at a certain operating voltage either of two possible values of current can exist: one at point B (non-saturated) and one at point F (saturated). Point D, in the "negative resistance" part of the curve is highly unstable.

Two methods are used to switch the circuit from one stable state to the other. One is to change the operating voltage (E_{a-c}) momentarily. Suppose the circuit is stable at point B. If E_{a-c} is raised to a value above that at point C the current will jump to some value beyond point G. If E_{a-c} is then returned to the bistable operating

voltage the current will decline to the other stable value at point F. On the other hand, if the current is stable at point F and E_{a-c} is reduced to a value below that at point E, the current will drop swiftly to a value below that at point A. If E_{a-c} is then returned to the bi-stable voltage the current will rise to a stable value at point B.

Applying a surge of control current is another way of switching the circuit from one stable state to the other. The total reactance curve shown in Figure 7 is that obtained without control current. If some d-c control current is applied the reactance curve will be shifted to the left as shown in Figure 9. This occurs because the control current now assists the a-c current in producing saturation. Consequently, the carrier winding circuit will reach the point of resonance at a lower value of a-c current. Figure 10 shows the resultant relationship between E_{a-c} and I_{a-c} when control current flows. Note that the circuit is no longer bi-stable at the operating voltage shown in Figure 8. At this voltage it is stable only in the saturated state. If the circuit is operating at point B in Figure 8, a surge of control current will switch it to the saturated state. When the control current declines again to zero the circuit will stabilize at operating point F. Notice, however, that a pulse of control current will not switch the circuit from the saturated state to the non-saturated state.

R1 in Figure 6 was placed in series with L1 and C1 to simplify the circuit. In practice the load resistance is usually connected in parallel with C1. This arrangement will produce the same effect described above if the parallel resistance has the proper value.

REFERENCES

For more thorough descriptions of magnetic circuits see the articles listed below.

(1) "Ferroresonant Flip -Flops" Carl Isborn, Electronics, April 1952.

(2) "An Unstable Nonlinear Circuit" Claude Summers, Elect. Engr., May 1940.

(3) "Critical Conditions in Ferroresonance", P. H. Odessey and E. Weber, AIEE Transactions V. 57, p. 444, Aug. 1938.

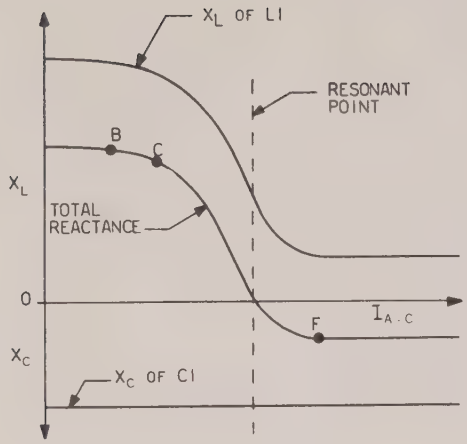
(4) "Non-Linear Circuits Applied to Relays" C. G. Suits, Elect. Engr. April 1933.

(5) "Non-Linear Circuits for Relay Applications" C. G. Suits, Elect. Engr., Dec. 1931.

(6) "Resonant Non-Linear Control Circuits" W. T. Thomson, AIEE Transactions, Aug. 1938.

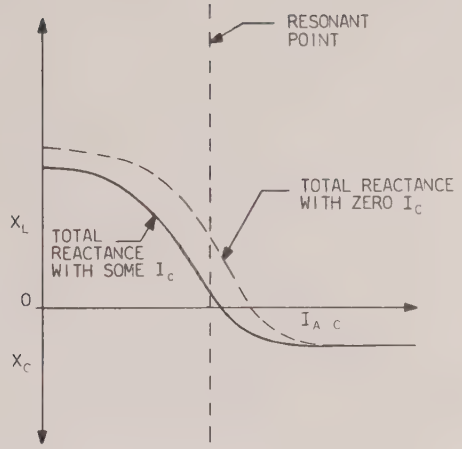
(7) "Resonant Theory Series Non-Linear Circuits" E. G. Keller, Journal of Franklin Institute, May 1938.

(8) "Studies in Non-Linear Circuits" C.G. Suits, AIEE Transactions, June 1931.



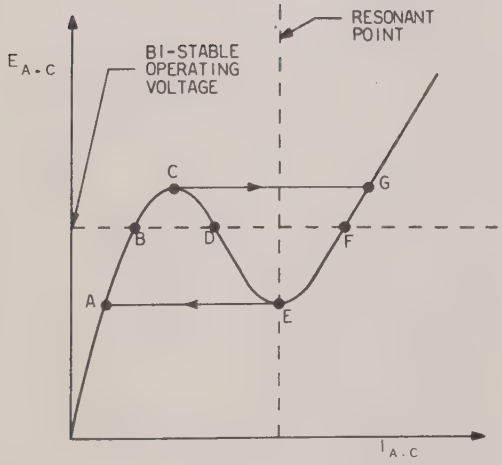
I_{A-C} VS REACTANCE AT ZERO I_C

FIGURE 7.



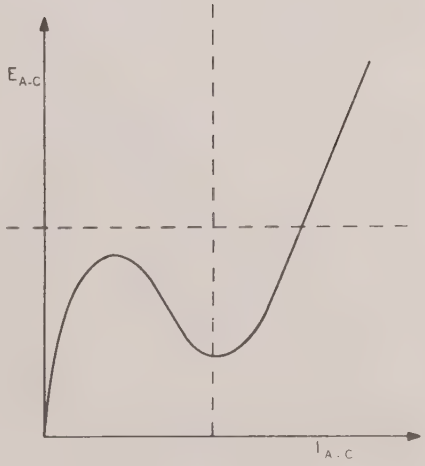
I_{A-C} VS REACTANCE WITH SOME I_C

FIGURE 9.



E_{A-C} VS I_{A-C} AT ZERO I_C

FIGURE 8.



E_{A-C} VS I_{A-C} WITH SOME I_C

FIGURE 10.

A RING COUNTER

Method of Obtaining Discrete Stable States. Several of the bistable circuits described under "FERRORESONANCE" can be connected in a ring to form a pulse counting device. Figure 11 shows a ring circuit made up of three saturable reactors which, consequently, has three discrete stable states. It is called a ring-of-three. The carrier winding circuits are connected in parallel to the carrier supply through a high impedance (C1). Only one reactor can be saturated at any given time for the following reason. If C1 were shorted, the voltage across all bistable combinations would rise high enough to cause all the reactors to saturate with carrier current alone. However, since carrier voltage is applied through C1, the voltage across all bistable combinations initially rises only until one reactor saturates and draws heavy current through its carrier winding. When this happens the voltage across all three is lowered due to the voltage drop across C1. The lowered voltage is high enough to maintain saturation in one reactor but not high enough to cause either of the other two to saturate if unaided by control current.

Referring to Figure 8, the voltage across one bistable combination originally rises to that at point C, then falls to a value between that at point C and that at point E. If more than one reactor began to saturate, the voltage across all would drop below the value at point E, and all but one would be forced into the non-saturated state. This circuit is analogous to three gas tubes connected in parallel to a d-c voltage through a high impedance. When voltage is applied, the potential across the tubes rises until one breaks down. Once this occurs the other tubes will not fire because their ionizing voltage is greater than the operating voltage of the tube already conducting.

Triggering the Ring Counter. One method of triggering the ring from one state to another is to lower the carrier voltage momentarily. Figure 11 shows a circuit designed to be triggered this way. Suppose SR2 is the saturated reactor. Then the high r-f output voltage at the junction of SR2 and C4 charges C5 through diode CR1. The lower r-f voltage at the outputs of SR3 and SR4 produces only a small charge on C8 and C11.

With the circuit in this condition, a current pulse is applied to the input. The current flowing through the control winding of SR1 lowers the reactance of its carrier winding to the point at which the inductance of SR1 and capacitance of C2 become series resonant. This lowers the voltage on the RF bus to such a value that SR2 is forced out of the saturated state. (Note that R2 keeps SR1 and C2 from latching in the high current condition.)

At the end of the input pulse, the voltage on the RF bus again rises until one of the reactors saturates. In this case, SR3 saturates first because it is already partially saturated by current flowing in its control winding as C6 discharges. The next input pulse returns SR3 to the non-saturated state and saturates SR4. Successive input pulses cause the saturated state to revolve around the ring in such a way that the lamps (I1, I2 and I3) indicate the number of pulses counted.

Rings-of-ten can be cascaded to provide decimal counters of any capacity.

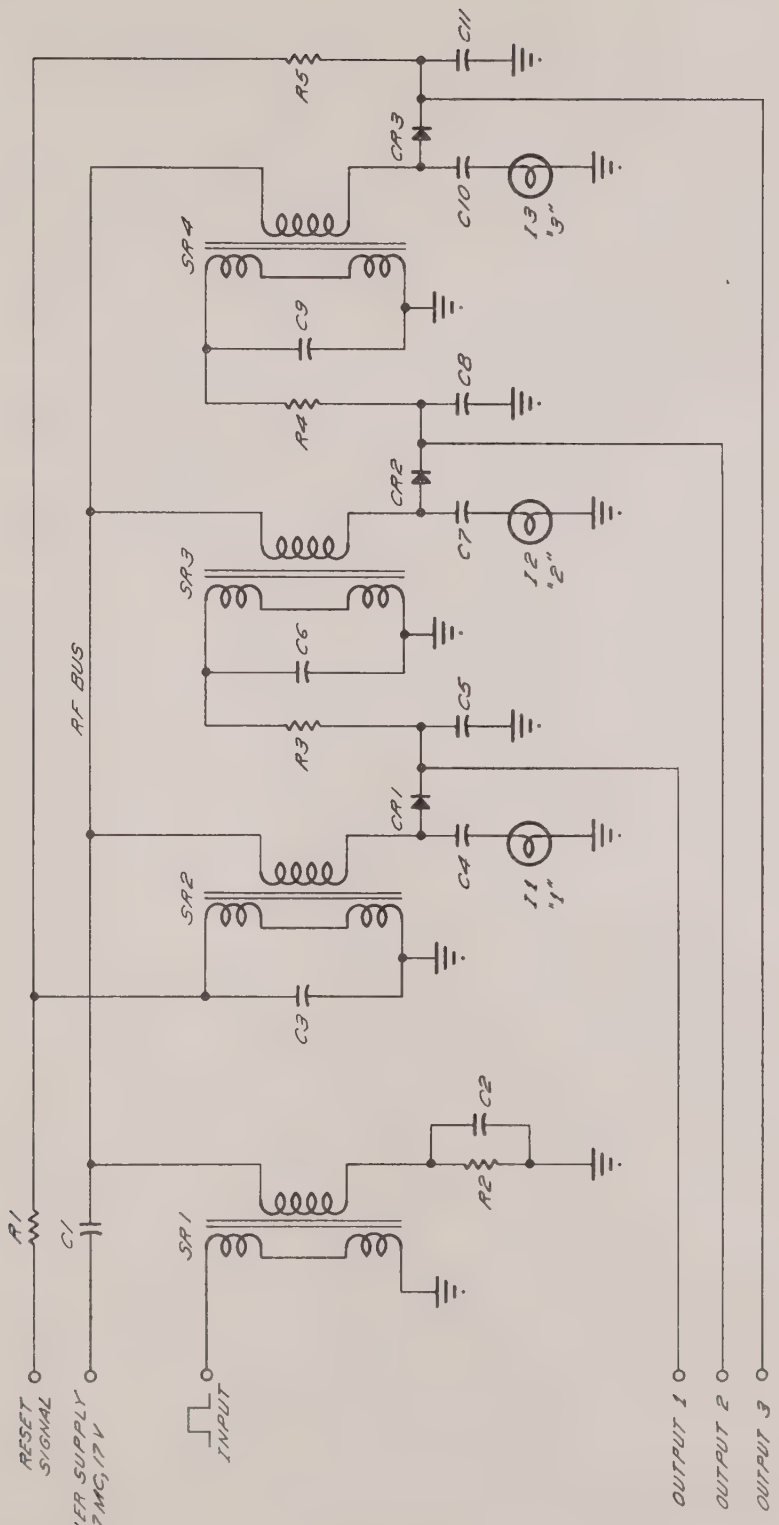


FIGURE 11. A RING-OF-THREE (WITH TRIGGERING SR)

INSTRUCTION MANUAL

MODEL 736
DUAL PRESET MAGNETIC
DECIMAL COUNTING UNIT

BERKELEY division
Beckman Instruments, Inc.

Richmond 4, California
27 June 1956

INTRODUCTION

The dual preset magnetic decimal counting unit is a direct-reading, plug-in electronic counter which emits output signals at any two selected number of counts. The unit counts from zero to nine, returning to zero on the tenth pulse. The number of input pulses received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. The operator selects the registered count at which each of the two output signals is to occur by positioning two 10-position rotary switches.

The unit contains a reliable new magnetic component, the Berkeley Ferristor*, which is used in place of the conventional vacuum tube. Ferristors do not deteriorate with use or age and cannot be damaged by shock, vibration or moisture. Since they generate so little heat that ventilation is unnecessary, the circuitry is protected by a dust-tight cabinet. Even unventilated the interior temperature is not high enough to cause the slow heat-deterioration that so often occurs in electronic devices. As an additional safeguard against breakdown most components are operated at less than 25% of component ratings.

SPECIFICATIONS

Count Indication	Direct reading decimal presentation
Input Requirements	Current pulse, 20 ma peak to peak into 15 mh and 300 ohms in series, 2 to 12 microsec. duration at 10% level.
Maximum Counting Rate	10,000 counts per second
Resolution of Paired Pulses	100 microseconds
Output Characteristics	See "Installation"
Reset to Zero	Requires voltage pulse ±20v ±20% into 4,000 ohms of at least 30 microsec. duration
Power Requirements	Carrier supply: 14 volts rms ±10% at 1.7 mcs, 1.5 watts.

*"Ferristor" is the trade-mark applied to saturable reactors manufactured by the Berkeley Division of Beckman Instruments, Inc.

	Bias supply: +300 volts d c ±10 per cent at 3 ma.
Plug-in connector	Standard Octal Plug
Dimensions	1 7/8" wide, 5 1/2" high, 3 1/2" deep
Weight	1 lb.

INSTALLATION

Location. The carrier supply impedance should be kept as low as possible. Therefore, mount the unit near as possible to the 14-volt carrier supply source. One method of doing this is to obtain the 14-volt supply from a step-down transformer whose primary is energized by about 180 volts. Do not locate the unit in a strong magnetic field unprotected by shielding.

Input. Connect the source of input current pulses to pin 1 of the DCU plug. The DCU will register one count each time the current at this pin rises from zero to at least 20 ma and returns to zero again. Input impedance is 15 mh in series with 300 ohms. The current pulse must have a duration of at least 2 microseconds but not more than 12 microseconds calculated at the 10 per cent level.

Output Characteristics. The unit produces three outputs:

1. A signal appears at pin 7 of the DCU plug whenever the unit is registering "9". When this pin is not connected to a load it carries a pulsating d-c voltage at the carrier frequency which averages +30 volts at count register "9", +3 volts at count register "0" thru "7" and +6 volts at count register "8".

2. A signal appears at pin 4 at preset count #1 (the digit set by the upper preset switch). If this pin is not loaded, it carries a steady d-c voltage of +30 volts when the DCU is registering the preset digit. When a digit one less than that preset is registering, it carries +6 volts. At any other count register it carries +3 volts.

The total current drawn from all three outputs at any instant should not exceed 5 ma. Calculation of permissable load should take into account the possibility that all output pins may be at a high voltage simultaneously. This would happen if both preset switches were set at "9" and the DCU were registering "9". In this case a total current drain of 5 ma would cause the average

Series pin 4 is connected through the control winding of a Ferristor to +30 volts d-c. When the DCU is registering preset count #1 virtually no current flows because only a few volts is developed across the varistor. At all other times considerable current flows. The varistor may be by-passed with a jumper if desired.

The output circuit associated with preset count #2 is identical to that associated with switch #1.

Pin 7 of the plug is permanently connected through diode CR115 to the output of SR110, the Ferristor which is saturated when the DCU is registering "9". In the Model 5840 Series counters the output of this pin is used to gate every tenth input pulse to another DCU.

MAINTENANCE

It is recommended that field maintenance be confined to replacing defective diodes and the indicating neon bulbs when they become dim. (The diodes are mounted in plug-in clips and can be replaced in the field without the aid of a soldering iron.) Due to the reliability of magnetic components, other defects will rarely develop. If other faults should occur, return the DCU to the Berkeley Division for repairs.

voltage at all output pins to drop to +25 volts.

Method of Presetting to Zero. To reset the unit to zero apply a voltage pulse to pin 6 of the DCU plug through a coupling capacitor. If a positive pulse is applied at the pin it must be from 16 to 24 volts in amplitude. If a negative reset pulse is used, it must have an amplitude between 26 and 34 volts. In either case the pulse duration must be at least 30 microseconds.

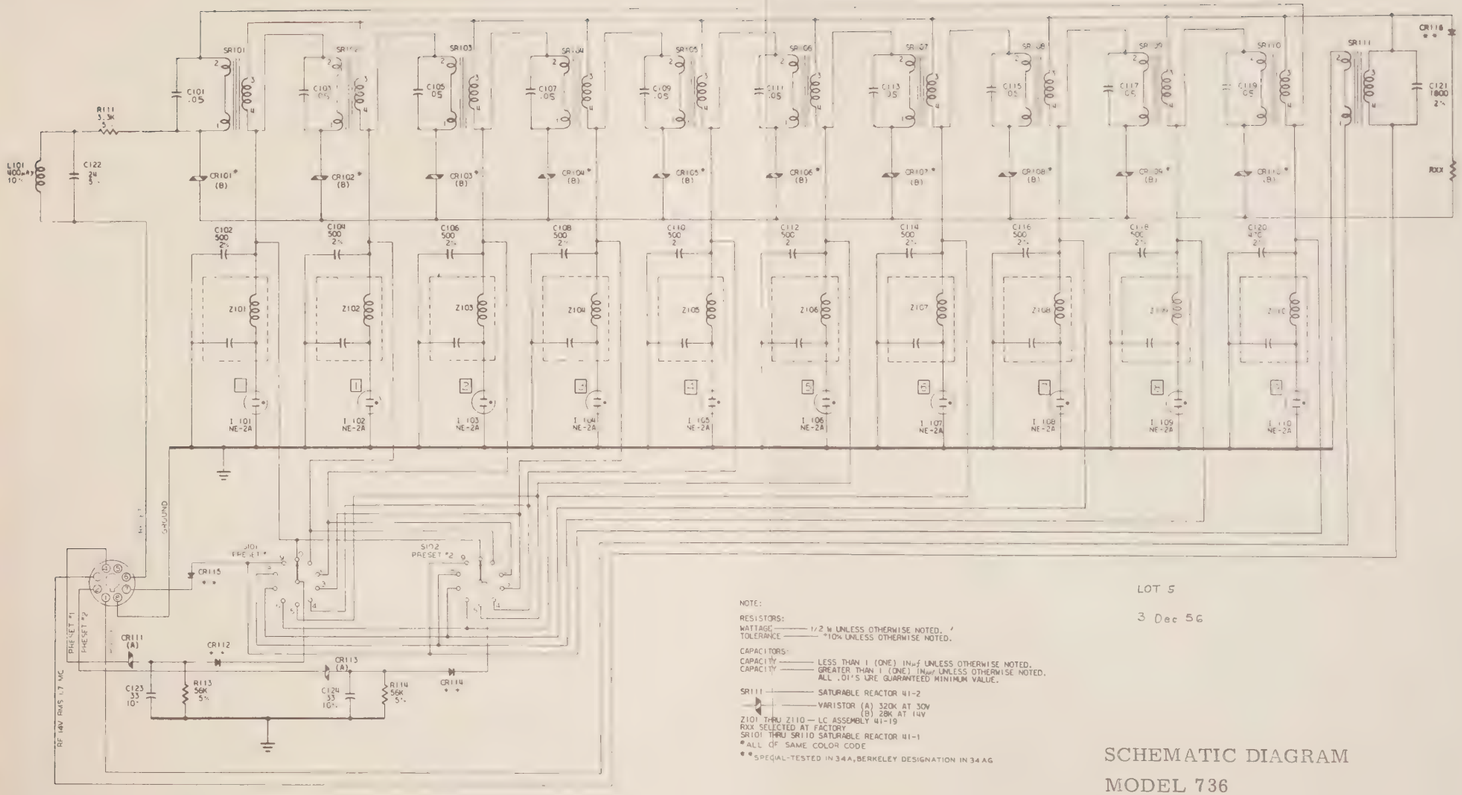
THEORY OF OPERATION

The unit is a ring counter like ring-of-three described under "A Ring Counter" in the section of this manual entitled "Elementary Circuits Using Ferristors." Since it contains ten Ferristors connected to form a ring-of-10, it has ten discreet stable states. As shown on the schematic, SR101 thru SR110 are the ten Ferristors comprising the ring. The unit is triggered from one state to another by momentarily reducing the applied carrier voltage. SR111 is the trigger Ferristor. It is connected so that a pulse of control current will reduce the reactance of its carrier winding to the point where the carrier winding and C121 become parallel resonnant, thus placing a high impedance in series between the carrier voltage source and the other Ferristors.

The reset voltage pulse applied at pin 6 draws control current through SR101, causing that Ferristor to saturate. When SR101 is saturated the unit registers "0".

Preset count switch #1 (S101) connects pin 4 of the plug through a varistor and a rectifier-filter network to the output of a selected Ferristor in the ring. When the selected Ferristor is saturated 22 to 25 volts rms appears across the capacitor connected between its carrier winding and ground. This voltage is rectified and filtered to produce about 30 volts d-c at pin 4. The polarity of this d-c output can be reversed simply by reversing the polarity of CR112.

The varistor CR111 has a high resistance when the voltage across it is low (for example, 10 megohms at 5 volts), but a much lower resistance when the applied voltages is relatively high (for example, 320 KΩ at 30 volts) This characteristic magnifies the variations in current at pin 4 which will be produced by variations in the voltage at the plate of CR112 This feature is useful when the current flowing at pin 4 is to be the controlling output of the DCU For example, in the Model 5840



NOTE:

RESISTORS:
WATTAGE ——— 1/2 W UNLESS OTHERWISE NOTED.
TOLERANCE ——— ±10% UNLESS OTHERWISE NOTED.

CAPACITORS:
CAPACITY ——— LESS THAN 1 (ONE) IN μf UNLESS OTHERWISE NOTED.
CAPACITY ——— GREATER THAN 1 (ONE) IN μμf UNLESS OTHERWISE NOTED.
ALL .01'S ARE GUARANTEED MINIMUM VALUE.

SR111 ——— SATURABLE REACTOR 41-2

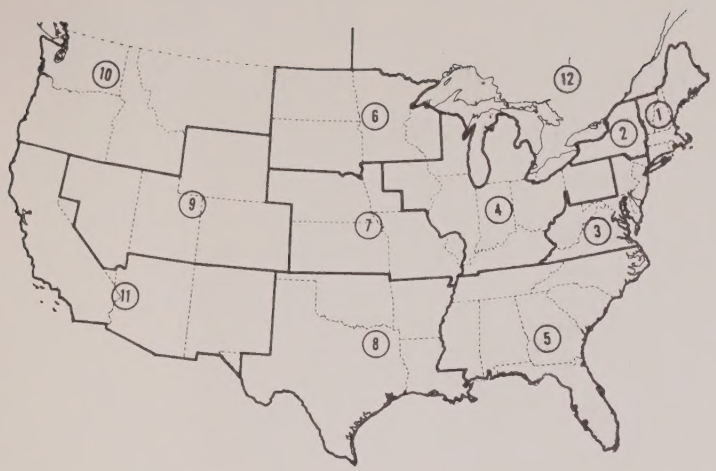
——— VARISTOR (A) 320K AT 30V
(B) 28K AT 14V

Z101 THRU Z110 — LC ASSEMBLY 41-19
RXX SELECTED AT FACTORY
SR101 THRU SR110 SATURABLE REACTOR 41-1
* ALL OF SAME COLOR CODE
** SPECIAL-TESTED IN 34A, BERKELEY DESIGNATION IN 34AG

LOT 5

3 Dec 56

SCHEMATIC DIAGRAM
MODEL 736
DECIMAL COUNTING UNIT
DWG. No. 736 D 1



FOR MORE INFORMATION

Detailed technical bulletins on all the equipment appearing in this catalog, as well as on similar equipment not shown, can be obtained from your nearest Beckman/Berkeley sales representative. He is also available for consultation and can offer valuable assistance in analyzing equipment needs and selecting instrumentation best suited to the job.

"Instrumental In Your Future"

BECKMAN/BERKELEY REPRESENTATIVES

1 BROGER INSTRUMENT SALES COMPANY, INC.

Boston Area
48 Pearl Street
Brookline 47, Massachusetts
Phone: BEacon 2-4804

New Haven 15, Connecticut
31 Broadway
P. O. Box 2917
Phone: SPruce 7-6279

2 SBM ASSOCIATES, INC.

Rochester 10, New York
177 Winton Road, North
Phone: OLympic 4-8440

Utica, New York
232 Roosevelt Drive
Phone: REdwood 2-4410

Binghamton, New York
Nowlan Road, R.D. No. 3
Phone: RAymond 2-2648

Syracuse, New York
1943 West Fayette Street
Phone: HOward 8-5041

3 GAWLER-KNOOP COMPANY

New York City Area
178 Eagle Rock Avenue
Roseland, New Jersey
Phone: CAldwell 6-4545
DIgby 4-2997 (N. Y. C.)

Washington, D. C. Area
8732 Flower Avenue
Silver Spring, Maryland
Phone: JUniper 5-7550

Philadelphia Area
835 Glenside Avenue
Wyncote, Pennsylvania
Phone: WAverly 7-1820

Baltimore Area
807 East Seminary Avenue
Towson 4, Maryland
Phone: ENterprise 9-3151

INTERNATIONAL SALES EXCEPT CANADA:

Beckman Instruments International, S.A.,
Geneva, Switzerland

Beckman Instruments, GmbH, Munich, Germany

Beckman Instruments, Ltd., Glenrothes, Scotland

4 RIDGWAY ASSOCIATES

Chicago 39, Illinois
6100 West North Avenue
Phone: TUxedo 9-5715

Indianapolis 2, Indiana
1224 North Capitol Avenue
Phone: MElrose 5-2401

Cleveland 31, Ohio
5917 Schaaf Road
Phone: LAfayette 4-1421

Dayton 32, Ohio
3898 Linden Avenue
Room 209 Arcade
Phone: CLearwater 2-5604

Detroit Area
3384 West Twelve Mile Rd.,
Berkley, Michigan
Phone: LIncoln 6-3312

5 MURPHY AND COTA

Atlanta 9, Georgia
2110 Peachtree Road, N.W.
Phone: TRinity 6-3020

Orlando, Florida
2319 E. South St.
Phone: GArden 4-2167

Winston-Salem, North Carolina
1106 Burke Street
Phone: PArk 4-0750

Huntsville, Alabama
Room 216
Electric Systems Center
Phone: JEfferson 9-8476

6 PINKNEY & HINE COMPANY

Minneapolis 3, Minnesota
1925 Nicollet Avenue
Phone: FEderal 8-0523

7 LEEMARK ASSOCIATES

Kansas City 15, Missouri
4021 West 86th Street
Phone: NIagara 2-3313

St. Louis 17, Missouri
2001 Big Bend Boulevard
Phone: MIssion 7-1470

8 DANNEMILLER-SMITH, INC.

Dallas 35, Texas
2712 West Mockingbird Lane
Phone: FLeetwood 7-8249

Houston 27, Texas
6218-B Westheimer Road
Phone: SUnset 2-7350

9 WILLIAMS & ASSOCIATES, INC.

Denver 22, Colorado
2261-63 South Albion Street
Phone: SKyline 6-9403

Salt Lake City, Utah
362 Pierpont Ave.
Phone: 328-3101

10 RUSH S. DRAKE ASSOCIATES, INC.

Seattle 44, Washington
1817 South Norman Street
Phone EAst 3-8545

Idaho Falls, Idaho
P. O. Box 2126
Phone: JAckson 2-7992

11 V. T. RUPP COMPANY

Los Angeles 26, California
307 Parkman Avenue
Phone: DUnkirk 7-8224

Albuquerque, New Mexico
1437 San Mateo, N.E.
Phone: 256-0798

San Diego 3, California
3445 - 5th Avenue
Phone: CYpress 8-9835

San Francisco Area
1182 Los Altos Avenue
Los Altos, California
Phone: 948-1483

12 R-O-R ASSOCIATES, LIMITED

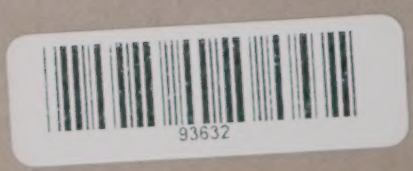
Toronto, Ontario
1470 Don Mills Road
Don Mills, Ontario
Phone HIckory 4-4429

Montreal, Quebec
3333 Cavendish Boulevard
Phone: HUnter 1-0700

Ottawa 3, Ontario
864 Lady Ellen Place
Phone: PArkway 9-1585

REVISED EDITION OF OCTOBER, 1961 • 10M

PRINTED IN U.S.A.


93632